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Council Staff

COMPILATION OF

INFORMATION ON SALMON AND STEELHEAD LOSSES

IN THE COLUMBIA RIVER BASIN

March 1986

NORTHWEST POWER PLANNING COUNCIL
850 S.W. Broadway, Suite 1100
Portland, Oregon 97205

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FOREWORD

The draft Compilation of Information on Salmon and Steelhead Losses in the Columbia River Basin was released initially in September 1985. Because of the extensive public interest in the initial draft, as indicated from the volume of oral and written comments received, the draft was revised and released for further comment in December 1985.

Many individuals and groups worked to produce this compilation. For the initial draft, preliminary portions of Chapters 3-5 were prepared by Council contractors Randall Schalk (Chapter 3) and Environmental Research and Technology, Inc. (Chapters 4 and 5). Information found in Appendix D also was prepared in draft form by Environmental Research and Technology, Inc. Council staff compiled and prepared Chapters 1, 2, and 6, and prepared Chapters 3-5 from information substantially provided in contractor reports. The Council's Losses and Goals Advisory Committee, comprised of individuals associated with fish and wildlife agencies, Indian tribes, utilities, Bonneville Power Administration, and the general public, provided information on data sources and reviewed chapter drafts. The revised draft was prepared by Council staff using information found in the initial draft as a basis and incorporating further information from comments received in the initial review period. The format of the revised draft is substantially different from the initial draft.

Copies of most reference materials discussed in this compilation are available for public review and copying in the Council's public reading room at its central office, 850 S.W. Broadway, Suite 1100, Portland, Oregon, weekdays between 8 a.m. and 5 p.m. Minimal copying charges may be levied.

Chapter 1
INTRODUCTION

1.0 THE NORTHWEST POWER PLANNING COUNCIL

The Northwest Power Planning Council (the "Council") was established pursuant to the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (16 U.S.C. 839 et seq., the "Act"). The Council was directed by the Act to develop a Columbia River Basin fish and wildlife program to protect, mitigate, and enhance fish and wildlife "affected by the development, operation and management" of hydroelectric facilities in the basin. (See Figure 1 -- Northwest Power Planning Council's Four-state Planning Area.)

Responding to Congressional direction to emphasize action over prolonged study, the Council's 1982 Fish and Wildlife Program included more than 200 action items calling for prompt implementation of fish and wildlife projects. However, the Council recognized that long-term program planning would require further definition of the scope of the Fish and Wildlife Program and establishment of program goals. Essential to these overall statements of purpose would be an understanding of the extent to which salmon and steelhead have been affected by the development and operation of the hydroelectric system and facilities. To serve these ends, the Council adopted program Section 201, which provides for a process leading to the development of goals:

> The Council will assess salmon and steelhead losses attributable to hydropower development and operations, state goals, adopt objectives, develop methods for measuring progress toward goals and objectives, and otherwise provide a systemwide framework for program measures and action items....

In April 1985 the Council adopted a work plan outlining a process for establishing this "systemwide framework," to be comprised of four principal elements: 1) a statement of losses, describing the salmon and steelhead production and production capability which have been diminished or destroyed

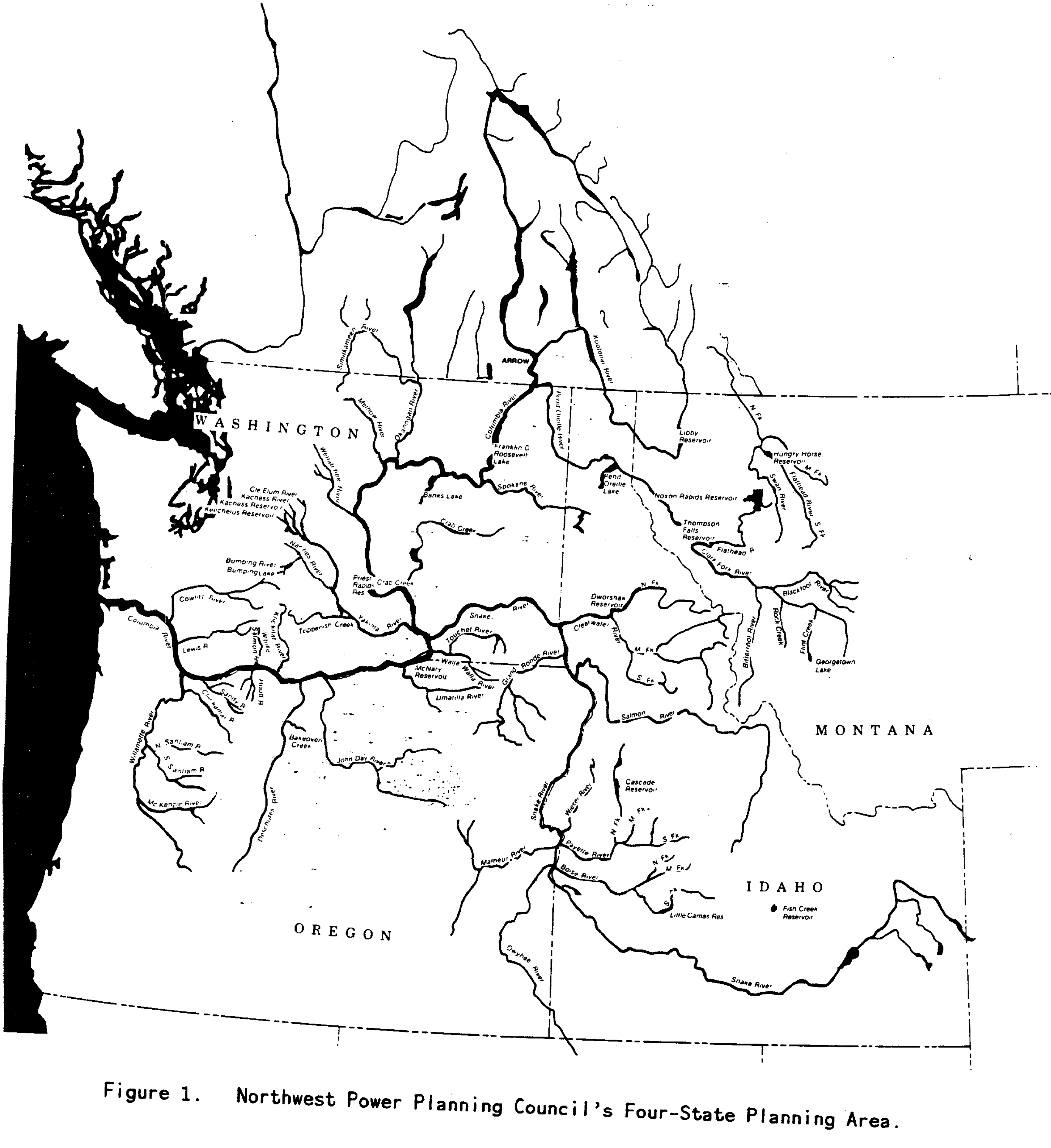

Figure 1. Northwest Power Planning Council's Four-State Planning Area.

by hydropower development and operations in the Columbia River Basin; 2) a statement of goals and systemwide objectives indicating the scope of fishing production to be funded under the Council's program and the major policies for determining the types and location of production to be emphasized; 3) production objectives, the series of short-term, geographically-specific and biologically-feasible production targets planned to lead together, over time, to achievement of long-term basinwide goals; and, 4) methods for measuring and accounting for progress toward goals and objectives.

This document describes salmon and steelhead losses attributable to all causes. As such, it comprises only the first step in the Council's assessment of salmon and steelhead losses attributable to hydropower development and operations. It does not reach conclusions on relative responsibilities for losses or specifically identify hydropower's contribution to those losses. A Council staff issue paper entitled "Contributions" will discuss the extent of hydropower responsibility for losses.[1]

From the beginning the Council has been aware that its judgment on goals likely would be a prudential judgment, not a judgment dictated by data. Reliable data are scarce for the predevelopment era. Although more recent data are plentiful, even very recent data may not be expressed in a way that enables comparative judgments (e.g., among fishing effort, timber harvest and trends in fish runs).

It is the Council staff's judgment, however, that the data must be taken as they are, and that further investment of time and effort scouring historical records is unjustified. The process of preparing this compilation has demonstrated to the Council staff that almost every facet of the data could be debated without end, yet further debate over the data would not achieve precision. The Council intends to make its prudential judgments taking those uncertainties into account.

1/ Council staff issue papers related to goals are described in the Council's "Work Plan for Development of a Program Framework," April 1985. The "Contributions Issue Paper" is scheduled for release in March 1986.

It is the Council staff's judgment that the data permit several broad conclusions regarding anadromous fish losses, as follows:

1.1 CHANGES IN SALMON AND STEELHEAD RUN SIZES (Chapter 2)

The most dramatic conclusion is the drastic decline in the size of fish runs (numerical loss). Estimates of the average annual salmon runs before development of the basin range from about 10 to 16 million fish. In contrast, the estimated current average annual run size is about 2.5 million fish. These estimates yield a net basinwide loss of about 7 to 14 million fish.

1.2 EFFECTS ON TRIBES (Chapter 3)

Chapter 3 documents the extensive reliance of Indian tribes on salmon and steelhead. While this reliance has not been determined with precision either in the aggregate or with respect to specific groups, there is no doubt that it was a dominant fact in the lives of many tribes. The decline in numbers of fish, combined with the shift of fish from the upper to lower basin (see Section 1.4), has had a serious effect on those tribes.

1.3 HABITAT LOSS AND DEGRADATION GENERALLY (Chapter 4)

There have been significant losses and degradation of salmon and steelhead habitat in the Columbia River Basin. Particularly severe was permanent blockage of habitat by large mainstem dams such as Chief Joseph and Grand Coulee dams and the Hells Canyon complex. The harmful effects of such projects are irreversible because it is not feasible to provide fish passage facilities for them. Even if these areas were planted with non-native anadromous fish stocks, those stocks could not migrate and return to spawn. Even dams that permit fish passage have inundated habitat, destroying spawning and rearing areas and increasing downstream migration time. It is estimated that salmon and steelhead habitat in the entire basin has decreased from about 14,666 miles of stream before 1850 to 10,073 miles of stream presently, a 31 percent loss all due to water development. Salmon and steelhead habitat loss in the Columbia River above Bonneville Dam (incuding the Snake River) also has been intensive, decreasing from 11,741 miles of stream before 1850 to 7,582 miles of stream, about a 35 percent loss.

While the lower river area below Bonneville Dam has suffered significant losses of spring chinook habitat, there has been much less habitat loss compared to upriver areas. In the Willamette River, habitat has been opened to additional anadromous fish species (fall chinook, summer steelhead) due to the construction of the fishway at Willamette Falls. In the Columbia River system below Bonneville Dam, salmon and steelhead habitat has decreased from 2,925 miles of stream to 2,491 miles of stream, about a 15 percent loss.

Throughout the Columbia River Basin, additional salmon and steelhead habitat has been degraded by forest and farming practices, waste disposal, and other factors. In some areas such habitat degradation has been extensive; but its effects are largely reversible.

1.4 LOSSES OF UPRIVER FISH RUNS AND HABITAT (Chapter 5)

The greatest losses of fish runs and habitat have occurred in the upper Columbia and upper Snake areas. These losses are largely unmitigated. Three general factors are responsible for loss of upriver fish runs: 1) Loss of habitat. See Section 1.3. 2) Passage mortalities at dams. Passage mortality is estimated at about 15 to 30 percent per dam for dowmstream migrants and 5 to 10 percent for upstream migrants. Cumulative juvenile passage mortality for untransported fish passing nine dams on the way to the ocean is approximately 77 to 96 percent. Adult passage mortality for fish passing nine dams on the way to spawning areas is approximately 37 to 51 percent. 3) Mixed-stock ocean fishery. In a mixed-stock fishery, upriver and wild runs already weakened by habitat and passage losses, are fished at the same rate as lower river runs (heavily hatchery-supplemented). As a result weaker upriver runs may be overfished.

1.5 EFFECTS OF MITIGATION (Chapter 6)

Efforts have been made to mitigate the effects of development. Two of these efforts have had major implications for the salmon and steelhead fisheries. First was a series of fishing regulations that in addition to restraining harvest also contributed to a shift from inriver harvest to ocean harvest of some stocks. Columbia River chinook salmon caught in ocean fisheries (including Canada and Alaska) now account for about 73 percent of total harvest.

Second was the development of large-scale hatchery production of salmon and steelhead. In 1949, hatchery programs were developed under the Mitchell Act (16 U.S.C. § 755). Most Mitchell Act hatchery fish are raised and released in the lower river, supporting the expansion of the lower river and ocean commercial fisheries. By the late 1960s, hatchery production of fall chinook and coho salmon and steelhead far surpassed natural production. Extensive production of hatchery fish has, along with permanent blockage by dams which eliminated some stocks, changed the genetic character (biological loss) of Columbia River Basin stocks. In addition, availability of large numbers of lower river hatchery fish causes overfishing of wild and upriver stocks in the mixed-stock harvest.

Chapter 2
ESTIMATE OF TOTAL LOSSES:
A NUMERICAL RANGE

2.1 INTRODUCTION

To estimate the total quantity of salmon and steelhead lost, two variables are required. These are the numbers of salmon and steelhead produced by the Columbia River Basin prior to Euroamerican development of the basin and numbers of salmon and steelhead produced currently. Subtraction of current run sizes from predevelopment run sizes equals the total quantifiable loss as defined here. This chapter details estimates of predevelopment run sizes, current run sizes, and the resultant loss ranges. [Note that the portion of the total loss attributable to hydropower will be discussed in the Hydropower Responsibility Issue Paper to be released in April 1986.]

2.2 ESTIMATES OF PREDEVELOPMENT RUN SIZES

2.2.1 Overview

Predevelopment run size has been estimated using different habitat-based and catch-based approaches. The various approaches are explained below.

2.2.2 Habitat-Based Approach

Run size can be estimated in terms of potential production of available habitat. In 1979 the Environmental Task Force of the Pacific Fishery Management Council estimated available habitat and potential production of each species for Columbia Basin salmon, but not for steelhead (Table 1). This estimate reflects conservative production estimates (PFMC 1985c) based on production "before water development blocked access to streams and before habitat was degraded." This is also the predevelopment (before 1850) definition used in this document.

Table 1 - Estimate of Columbia River Basin salmon and steelhead run sizes prior to 1850 based on estimates of available habitat.[1]

	Chinook[2]	Coho	Sockeye	Chum	Steelhead
Columbia River mainstem and tributaries downstream from Bonneville Dam	1,040,000	901,000		950,000	
Snake River	1,400,000	200,000	150,000		
Columbia River mainstem and tributaries upstream from Bonneville Dam not including the Snake River	1,000,000	100,000	500,000		
Total Columbia River Basin	3,440,000	1,201,000	650,000	950,000	2,042,000
Total salmon	6,241,000				
Total salmon and steelhead	8,283,000				

[1]Developed from Pacific Fishery Management Council (1979), Table 1.

[2]Spring, summer, and fall chinook.

Table 1 lists an estimated total potential production for salmon as over 6.2 million fish. Assuming that coho salmon production approximately equals that of steelhead for individuals produced per mile of habitat, steelhead potential production can be estimated using Fulton's (1970) work. Fulton estimated that there was a ratio of approximately 1.7 to 1 of steelhead to coho habitat in the Columbia Basin. Using this ratio, steelhead production equaled about 2,042,000 fish (1.7 x 1,201,000) prior to 1850. Salmon and steelhead production prior to development of the basin would be approximately 8.3 million (6.24 million plus 2.04 million) using this method.

2.2.3 Catch Approach

A less conservative estimate for calculating total run size prior to 1850 can be made using maximum catch records. Table A-1 (Appendix A) shows the maximum chinook catch as 2.3 million fish in 1883. The catch remained fairly consistent from 1880 to 1920 -- about 1.5 million chinook. However, in the 1880s the catch was mostly summer chinook stocks while from about 1890 through 1920 the catch was sustained by fishing on later runs, i.e., fall chinook (Figures 2 and 3). By 1920 the catch was estimated to be one-half fall chinook while in the 1880s it had been almost entirely summer chinook. Assuming that the ratio of summer chinook to fall chinook was the same in the 1880s as in 1920 (2 to 1), then it is reasonable to assume that the average catch of fall chinook was 1,150,000 fish (50 percent of the 2.3 million summer chinook catch from 1883). Also, assuming that there was a symmetric distribution of spring and fall chinook, then the spring chinook run was also approximately 1,150,000 fish. Thus, the total capability of the river can be estimated as 4.6 million chinook of all races.

Using these numbers and the maximum catch numbers for other species (Beiningen 1976a), a run size range can be computed (Table 2). In computing this range, catch efficiency figures assumed by some analysts of 50 percent (Junge 1980, Chapman 1982 for coho salmon, Henry 1953 for chum salmon), 67 percent (Koch 1976), and 85 percent (Chapman, 1985) are used. These computations estimate a total Columbia Basin predevelopment run size range of about 10 to 16 million salmon and steelhead.

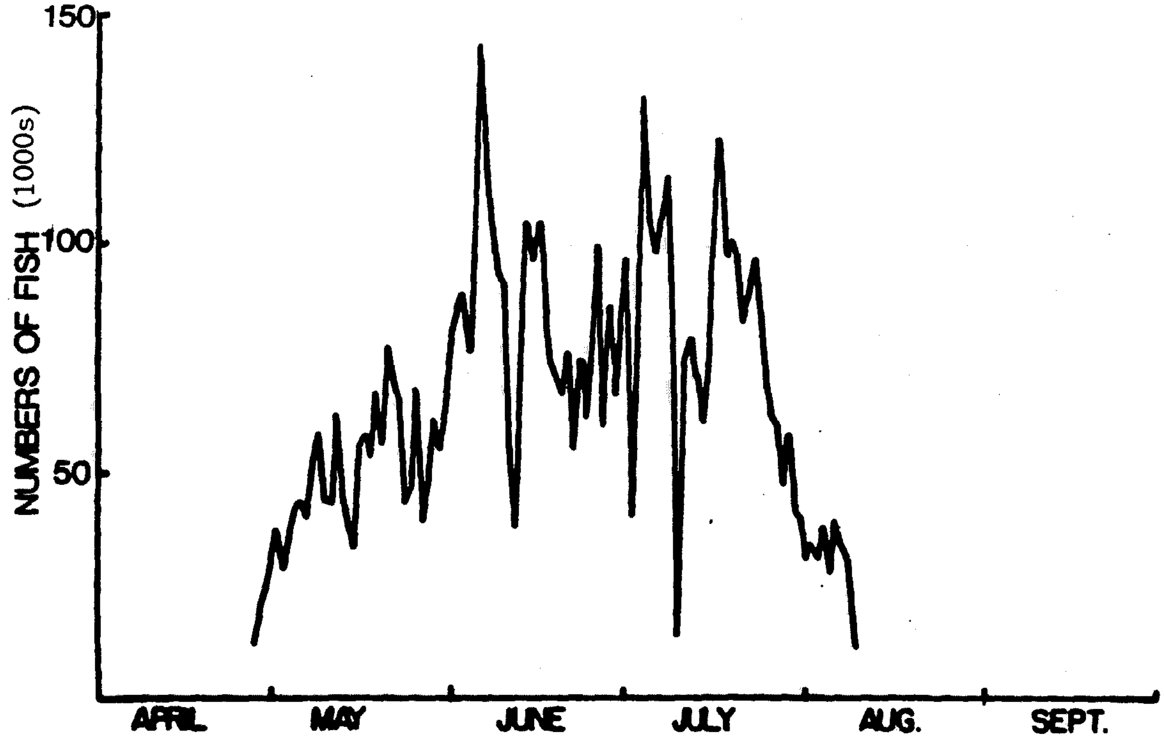

Figure 2. Timing of chinook runs in the Columbia River in 1878 showing dominant summer component at that time (Whitney and White 1984).

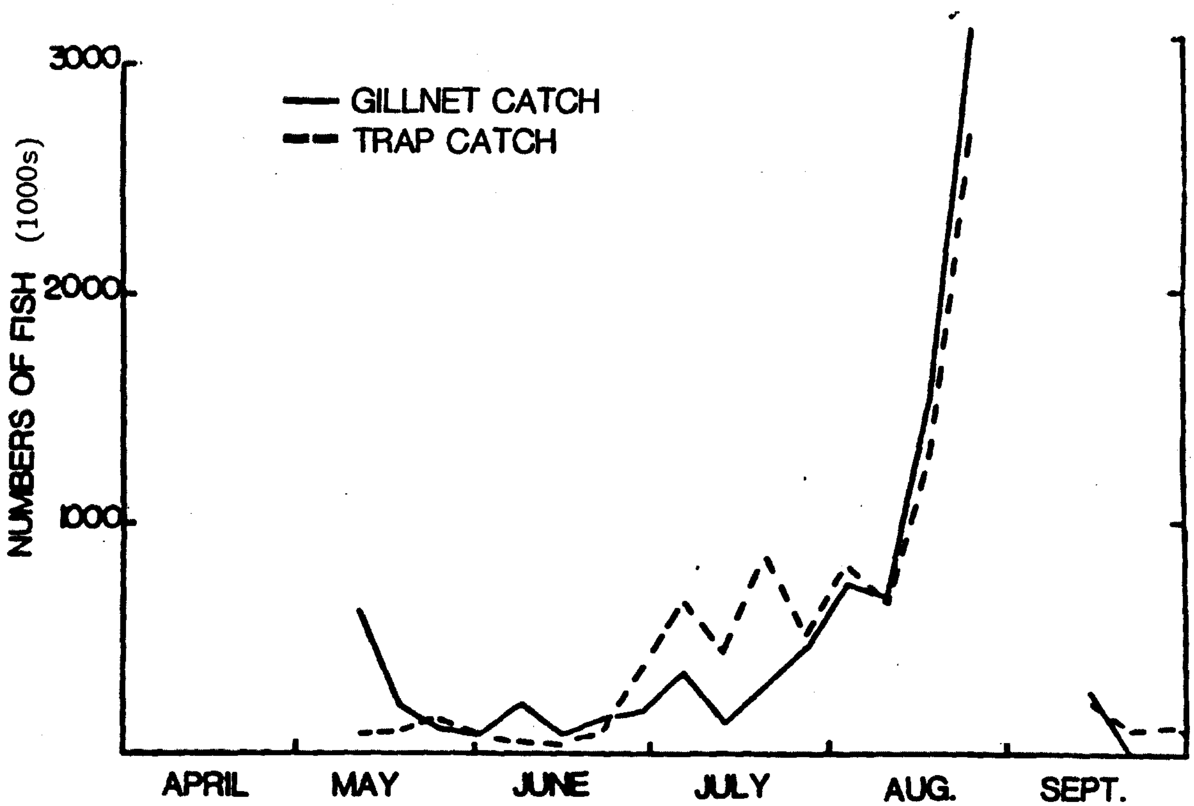

Figure 3. Timing of chinook runs in the Columbia River in 1919 showing decline of summer component (Whitney and White 1984).

Table 2 - Estimate of annual Columbia Basin run size based on maximum peak-year catch.

Species	Number of Fish Caught	Run Size Estimates[1] 85% Catch Efficiency Basis		67% Catch Efficiency Basis		50% Catch Efficiency Basis
Spring chinook	1,150,000	1,353,000	-	1,716,000	-	2,300,000
Summer chinook	2,300,000	2,706,000	-	3,433,000	-	4,600,000
Fall chinook	1,150,000	1,353,000	-	1,716,000	-	2,300,000
Sockeye	1,300,000	1,529,000	-	1,940,000	-	2,600,000
Coho	890,000	1,047,000	-	1,328,000	-	1,780,000
Chum	697,000	820,000	-	1,040,000	-	1,394,000
Steelhead	674,000	793,000	-	1,006,000	-	1,348,000
Total salmon and steelhead	8,161,000	9,601,000	-	12,179,000	-	16,322,000

[1] Estimate calculated by dividing number of fish caught by estimated catch efficiencies of 0.85, 0.67, or 0.50 (proportions of run caught).

Another method for estimating predevelopment run sizes in the Columbia Basin, similar to that detailed above, is outlined in Chapman (1985). Chapman estimates peak runs in the last half of the 1800s based on five-year mean peak harvest and mean weights (Table 3). Sockeye catches were calculated on the basis of ratios of fish wheel catches to total catch; spring chinook on the basis of catch timing and abundance relative to summer chinook; and coho on the basis of the first peak inriver catches. Optimum harvest rates are estimated by Chapman to be 77 percent for coho, 62 percent for sockeye, 68 percent for chinook, 69 percent for steelhead, and 30 percent for chum. However, Chapman estimates that an 80 to 85 percent harvest rate (catch efficiency) is probable, assuming that overfishing caused the declines in individual species of salmon and steelhead observed in the 1880s to 1920s period. He therefore estimates the predevelopment total Columbia Basin salmon and steelhead run to be about 8 to 10 million fish.

Table 3 - Estimate of annual Columbia Basin run size based on maximum five-year mean catch using Chapman (1985) catch efficiency numbers.

		Run Size Estimates		
Species	Number of Fish Caught	Optimum Harvest Rate		85% Catch Efficiency Basis
Spring chinook	400,000	588,000	(68%)	471,000
Summer chinook	1,700,000	2,500,000	(68%)	2,000,000
Fall chinook	1,100,000	1,618,000	(68%)	1,294,000
Sockeye	1,905,000	3,073,000	(62%)	2,241,000
Coho	605,000	786,000	(77%)	712,000
Chum	359,000	1,197,000	(30%)	422,000
Steelhead	382,000	554,000	(69%)	449,000
Total salmon and steelhead	6,451,000	10,316,000		7,589,000

Using Chapman's estimates of catch for each species and applying the 50 percent and 67 percent catch efficiencies used in addition to the 85 percent catch efficiency in the maximum peak-year catch method detailed previously (Table 2), the run size range can be estimated as about 10 to 13 million fish (Table 4).

Table 4 - Estimate of annual Columbia Basin run size based on maximum five-year mean catch using 67 and 50 percent catch efficiency numbers.

Species	Number of Fish Caught	Run Size Estimates: 67% Catch Efficiency Basis		Run Size Estimates: 50% Catch Efficiency Basis
Spring chinook	400,000	597,000	-	800,000
Summer chinook	1,700,000	2,537,000	-	3,400,000
Fall chinook	1,100,000	1,642,000	-	2,200,000
Sockeye	1,905,000	2,843,000	-	3,810,000
Coho	605,000	903,000	-	1,210,000
Chum	359,000	536,000	-	718,000
Steelhead	382,000	570,000	-	764,000
Total Salmon and Steelhead	6,451,000	9,628,000	-	12,902,000

A third method of estimating predevelopment salmon and steelhead run sizes for the Columbia Basin has been proposed by the Bonneville Power Administration (1984a) (hereinafter Bonneville). The source of the Bonneville estimate was a publication by Tollafson and Murrat (1959), with additional material from Rich (1922), and a rough calculation based on the total catch of salmon by fish wheels with the assumption that fish wheels took 5 percent of the total run (Donaldson and Cramer, 1971). Using this method, Bonneville estimated that the annual Columbia Basin salmon and steelhead run was as high as 350 million fish eight decades ago. This was apparently a misprint and the actual number computed was 35 million.

2.2.4 Range

The methods identified above estimate a range of about 8 to 35 million salmon and steelhead produced annually in the Columbia Basin prior to development. It is important to identify the relative validity of the numbers estimated. The habitat-based estimate and the Bonneville estimate can be eliminated from the range. The habitat-based estimate is based on extremely conservative data and the PFMC reports that it doesn't reflect a realistic run size. The Bonneville estimate is based on an unrealistically high fish wheel catch of 1.75 million fish (5 percent of 35 million). The maximum catch that can be estimated for the lower river commercial fishery (this includes fish wheel catch) is 8.161 million fish (see Table 2). Fish wheels caught an average of about 7 percent of the total lower river commercial harvest according to Smith (1979). The maximum catch of the fish wheels was therefore about 7 percent of 8.161 million fish, or 571,270 fish. If fish wheels caught 5 percent of the total run, then the total run estimate using Bonneville's method should be about 11.4 million fish. This estimate is within the aboriginal run size range estimate of 8 to 16 million fish.

Considering the above, the range that is most reflective of the predevelopment run size is therefore about 8 to 16 million fish. Within this range, 10 to 16 million is probably the most reasonable considering that the 8 million estimate is based on lower river commercial catches that do not include any Indian, sport, ocean commercial, or upper river non-Indian commercial/subsistence harvest. Indian and upper river non-Indian commercial/subsistence harvest also occurred throughout the 1880 to 1920 period. In addition, a building sport and ocean commercial harvest occurred after the turn of the century. Therefore, even if there was an overall harvest rate of 85 percent, only a portion of this overall harvest occurred in the lower river commercial fishery and the 50 to 67 percent harvest rates (10-16 million fish) are probably more reflective of this portion of the total harvest than is the 85 percent figure (8-10 million fish). It should also be noted that the 1880 to 1920 lower river commercial catch and therefore estimated run size are based on a time when some environmental degradation had already occurred in the basin. Therefore the 50 to 67 percent harvest rates not only allow for the harvest that occurred in other than the lower river commercial fisheries, but also for a lowered basin productivity because of Euroamerican development of the basin prior to the 1880 to 1920 period.

2.3 ESTIMATES OF CURRENT RUN SIZE

The estimation of the current run size is complicated by both conceptual and data problems. For example, the run size estimates will differ depending on which stage of the life cycle the fish are counted. This conceptual problem is partially resolved by identifying where in the life cycle the current production is being estimated. However, the data problem never fully resolves itself since catch numbers and dam counts never give a complete picture of the population under study. For example, estimation of total current production from the Columbia River Basin by using counts of fish passing Bonneville Dam requires some understanding of the inriver and ocean harvest, tributary productivity below Bonneville Dam, ocean mortality, and other factors affecting the juveniles as they move from spawning grounds to the ocean. Recognizing these shortcomings and problems in estimation, it is still possible to estimate total current production in the basin with some degree of confidence. This has been done by the Washington Department of Fisheries, as displayed on Table 5.

Table 5 shows an estimate of total current production of salmon and steelhead for the Columbia Basin of about 2.5 million fish annually. This estimate includes the following assumptions. The ocean catch/inriver run factors represent estimates based primarily on coded-wire tag recoveries and from interpretation of inriver data from Pacific Fishery Management Council 1985 reports. The two sources are combined because tag recoveries are available for catch, but not for most escapement categories. These values were developed to be used with the 1977-81 averages. Since 1974-83 averages are similar, they may apply to the 10-year run size averages as well. For coho, the ocean catch rate has been significantly reduced in 1984-85 from 2:1 (2 caught for every 1 that escaped to spawn) to about 0.5:1, so it is not appropriate to use the latter expansion factor for the 1984 data.

Table 5 - Estimate of current run size (total adult production) for the Columbia River salmon and steelhead.

	Avg.[1] Ocean Catch 1974-83	Avg.[1] Ocean Catch 1977-81	Ocean Catch 1984	Ratio of[5] Ocean Catch/ Inriver Run	Estimated Total Current Run Size Using 5-Year Avg. (1977-81)
Below Bonneville Dam					
Lower river spring[2] chinook	94,700[3]	95,800	113,100	1.5[6]	239,500
Lower river fall hatchery chinook	138,600	131,600	109,900	1.4[9]	315,800
Lower river fall natural chinook	25,300	26,300	13,900	3.4[8]	115,700
Coho	268,700	237,900[4]	382,900	2.0	713,700
Chum[12]	2,000[15]	-	2,000[15]	0.0	2,000[13]
Winter steelhead[11]	67,500[15]	-	45,600[15]	0.0	67,500[13]
					1,454,200
Above Bonneville Dam					
Upper river spring chinook	81,900	83,600	47,400	0.1[7]	92,000
Summer chinook	27,700	28,400	22,400	1.7[14]	76,700
Upper river fall hatchery chinook	107,300	101,200	46,900	2.3[9]	334,000
Upper river fall natural chinook	89,500	81,900	133,100	3.4[9]	360,400
Sockeye[11]	58,200[15]	-	161,600[15]	0.0	58,200[13]
Summer steelhead[11]	143,400[15]	-	366,300[15]	0.0	143,400[13]
					1,064,700
Total Columbia River Basin					2,518,900

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[1]PFMC, Appendix B, March 1985, for chinook and coho.

[2]Includes some jack salmon.

[3]Includes some spring chinook destined for upper Columbia River.

[4]1979-81.

[5]Comparable to 1977-82 average return year (1979-81 for coho).

[6]Calculated using data from agency reports on chinook stock status, U.S./Canada Technical Committee on chinook salmon.

[7]Calculated using coded-wire tag data from Klickitat, Carson and Leavenworth releases and PFMC (March 1985).

[8]Assumed equal to upper Columbia River fall natural, based on similarity in ocean distribution of coded-wire tag recoveries.

[9]Based on data from U.S./Canada Technical Committee on chinook salmon and inriver data from PFMC (March 1985).

[10]Calculated for unweighted average of late and early coho stocks using U.S./Canada Joint Technical Report (November 1975) and inriver data from PMFC (March 1985).

[11]Extracted from status report, Columbia River Runs and Fisheries (1960-1983), ODFW/WDF (1984).

[12]From Stock Assessment of Columbia River Salmonids, Volume II, Bonneville Power Administration (1985).

[13]Represents 10-year (1974-83) average. Five-year average not available.

[14]Assumed mid-Columbia and Snake portions of run are 50 percent each, and that ratio is average of these two (3.4 for mid-Columbia and 0.1 for Snake).

[15]These figures are for adult return to the river. Insignificant ocean harvest occurs on these stocks.

2.4 ESTIMATES OF TOTAL LOSSES

As stated in section 2.1, the total annual loss of Columbia Basin salmon and steelhead can be computed by subtracting the current run size from the predevelopment run size. By doing so, a range of loss of about 7 to 14 million salmon and steelhead can be computed (Table 6). This loss is attributable to all the developmental factors identified in this report (hydropower, fishing, logging, mining, irrigation, agriculture, grazing, urbanization/pollution, and miscellaneous impacts).

Table 6 - Estimated total loss of Columbia Basin salmon and steelhead.

Species	Predevelopment Run Size (Range)		Current Run Size	Loss (Range)	
	67% Catch Efficiency Basis[1]	50% Catch Efficiency Basis[2]		67% Catch Efficiency Basis	50% Catch Efficiency Basis
Spring chinook	597,000 -	2,300,000	331,000	266,000 -	1,969,000
Summer chinook	2,537,000 -	4,600,000	125,000	2,412,000 -	4,475,000
Fall chinook	1,642,000 -	2,300,000	1,126,000	516,000 -	1,174,000
Sockeye[2]	2,843,000 -	2,600,000	58,000	2,785,000 -	2,542,000
Coho	903,000 -	1,780,000	714,000	189,000 -	1,066,000
Chum	536,000 -	1,394,000	2,000	534,000 -	1,392,000
Steelhead	570,000 -	1,348,000	211,000	359,000 -	1,137,000
Total salmon and steelhead	9,628,000 -	16,322,000	2,567,000	7,061,000 -	13,755,000

[1]See Table 4, Column 2, maximum five-year mean catch.

[2]See Table 2, Column 4, maximum peak-year catch.

The loss can be broken down geographically into the areas above and below Bonneville Dam. Chapman (1985) identifies the percentage of the catch that was produced above and below Bonneville Dam. According to his estimates, based on stream miles, 18 percent of steelhead, 17 percent of spring chinook, 47 percent of fall chinook, and 52 percent of coho were produced below the point in the Columbia Basin where Bonneville Dam now stands. He states that all sockeye and summer chinook were produced above this point in predevelopment times. For the purposes of this compilation it will be assumed, based on habitat preference, that all of the chum and winter steelhead were produced below this point in predevelopment times and that all of the summer steelhead were produced above this point in predevelopment times. Although summer steelhead were present in lower river tributaries and chum and winter steelhead were found above Bonneville Dam, the amount of each species in these areas was very small and insignificant for purposes of these calculations. Using these percentages, the numbers of fish that once were produced above and below Bonneville Dam can be estimated. Components of the current run have been identified as "upper" or "lower" (Bonneville Dam being the dividing point) in Table 5. Once again, by subtracting predevelopment run sizes from current run sizes, the loss above and below Bonneville Dam can be computed (Table 7 and Table 8).

Table 7 - Estimated loss of salmon and steelhead produced above Bonneville Dam.

Species	Predevelopment Run Size (Range)		Current Run Size	Loss (Range)	
	67% Catch Efficiency Basis	50% Catch Efficiency Basis		67% Catch Efficiency Basis	50% Catch Efficiency Basis
Spring chinook	496,000 -	1,909,000	92,000	404,000 -	1,817,000
Summer chinook	2,537,000 -	4,600,000	62,000	2,475,000 -	4,538,000
Fall chinook	870,000 -	1,219,000	694,000	176,000 -	525,000
Sockeye	2,843,000 -	2,600,000	58,000	2,785,000 -	2,542,000
Coho	479,000 -	854,000	---	479,000 -	854,000
Chum	-----	-----	---	-----	-----
Summer steelhead	467,000 -	1,105,000	143,000	324,000 -	962,000
Total salmon and steelhead	7,692,000 -	12,287,000	1,049,000	6,643,000 -	11,238,000

Table 8 - Estimated loss of salmon and steelhead produced below Bonneville Dam.

Species	Predevelopment Run Size (Range)		Current Run Size	Loss (Range)	
	67% Catch Efficiency Basis	50% Catch Efficiency Basis		67% Catch Efficiency Basis	50% Catch Efficiency Basis
Spring chinook	101,000 -	391,000	240,000	(-139,000)[1] -	151,000
Summer chinook	-------- -	--------	-----	-------- -	-----
Fall chinook	772,000 -	1,081,000	431,000	344,000 -	650,000
Sockeye	-------- -	-------	-----	-------- -	-----
Coho	424,000 -	926,000	714,000	(-290,000)[1] -	212,000
Chum	536,000 -	1,392,000	2,000	534,000 -	1,392,000
Winter steelhead	103,000 -	243,000	68,000	35,000 -	175,000
Total salmon and steelhead	1,936,000 -	4,033,000	1,455,000	484,000 -	2,580,000

[1]Negative numbers reflect increases in production.

Table 7 displays the estimated loss of salmon and steelhead stocks above Bonneville Dam as between about 7 and 11 million fish annually. Table 8 displays the estimated loss of salmon and steelhead stocks below Bonneville Dam as between about 0.5 to 2.6 million fish annually. Although the difference in the the size of these numbers is large, this difference is reasonable considering the relative magnitude and severity of development above and below Bonneville Dam as detailed in Chapter 5. Because these estimates are not derived by the same range of methods used in estimating the overall basinwide loss figures, the two are not precisely comparable. Nevertheless, one can say that the upriver losses are substantial in relation to the lower river losses, and probably comprise significantly more than half of the total.

2.5 ALTERNATIVE ESTIMATE OF PREDEVELOPMENT RUN SIZE AND TOTAL LOSS

Data presented in the previous sections of this chapter can be combined in alternative methods to arrive at other estimates of predevelopment run size and total loss. The following represents one such alternative method. The results are shown in Table 9. The difference between this approach and the previous approach is in selection of a lower river commercial catch size, the addition of upriver Indian and settler catches, and the selection of catch efficiencies used to calculate spawning escapement.

Table 9 - Alternative estimate of predevelopment run size of Columbia Basin salmon and steelhead.

	Lower River Commercial Catch		Other Catch		Total Catch		Estimated Predevelopment Run Size	
Species	Maximum Peak Year	Maximum Five-Year Mean	Indian Catch in 1880 to 1920	Settler Catch in 1880 to 1920	Maximum Peak Year	Maximum Five-Year Mean	Maximum Peak Year (80% Catch Efficiency)	Maximum Five-Year Mean (67% Catch Efficiency)
Spring chinook	1,150,000	400,000	38,000	38,000	1,226,000	476,000	1,530,000	710,000
Summer chinook	2,300,000	1,700,000	98,000	98,000	2,496,000	1,896,000	3,120,000	2,830,000
Fall chinook	1,150,000	1,100,000	56,000	56,000	1,262,000	1,212,000	1,580,000	1,810,000
Sockeye	1,900,000	1,900,000	500,000	500,000	2,900,000	2,900,000	3,630,000	4,330,000
Coho	890,000	700,000	78,000	78,000	1,046,000	856,000	1,310,000	1,280,000
Chum	697,000	360,000	41,000	41,000	778,000	441,000	970,000	660,000
Steelhead	674,000	430,000	68,000	68,000	810,000	566,000	1,010,000	850,000
Total	8,761,000	6,590,000	879,000	879,000	10,518,000	8,347,000	13,150,000	12,470,000

"Maximum Peak Year" catch for the lower river used in this estimate is from Table 2 except that sockeye catch is increased from 1.3 million fish to 1.9 million fish because it seems reasonable that the "peak catch" must be at least as great at the "five year mean" which is 1.9 million fish. The "Maximum Five-year Mean" catch is from Table 3 except that coho and steelhead have been increased to 700,000 and 430,000 fish, respectively, to reflect all-time maximum five-year mean catch sizes (1925-29 and 1923-27 respectively) as opposed to Chapman's pre-1920s maximum five-year mean peak catches.

As discussed in Section 2.2.4, additional harvest should be added to lower river commercial catch to estimate run size, otherwise the estimate would be overly conservative. This can be accomplished for Indian catch as follows. Predevelopment Indian catch is estimated to be 4.5 to 5.6 million fish (see Chapter 3, Table 12). One commentor estimates that Indian populations were one-sixth of predevelopment in the 1880 to 1920 period when peak lower river commercial catches occurred (Chapman 1985). Using these figures, Indian catch in 1880 to 1920 is estimated as displayed in Column 4 of Table 9. It should be recognized that even though Indian populations had dropped to one-sixth of those in predevelopment times, the drop in catch was probably not proportional because only a small portion of tribal members ever fished for tribal subsistence and the tribes sold an ever increasing portion of their catch in the commercial market after the Euroamericans settled in the basin. These factors support the proposition that the catch of Indians fishing in the 1880 to 1920 period was greater than one-sixth of that in predevelopment times.

A settler catch equal to the Indian catch is included in Table 9. This is reasonable considering that in the late 1800s the Indian population was about 10,000 while the settler population was 750,000 (see Section 5.8 Urbanization/Pollution) and the Indian populations presumably relied on fishing more than the settler population. Catches of the settlers are referred to in sections 5.2.3.5 and 5.2.3.6, while the need to control settler catches by harvest regulation in the late 1800s is reflected in Tables 17 and 18. Rather than assume these population levels and activities did not exist, it is assumed that they had equal effect as the Indian effort.

Finally, the total calculated catch is converted to total run size by dividing by selected catch efficiencies. Another point that can arguably be made about the data involves reducing the range of commercial catch efficiencies that are used to estimate predevelopment run size. The five-year mean is an average catch; therefore, the 67 percent catch efficiency is probably most appropriate for expanding this number because this represents an average catch. The 80-85 percent catch efficiency is probably most realistically applied to the maximum peak year catch because this catch efficiency represents peak efficiency of harvest. The 80 percent catch efficiency is selected in this range to recognize that the decline in run sizes was not only due to overfishing but environmental degradation as well. As noted in Section 2.2.4, basin productivity was lower because of Euroamerican development in the 1880 to 1920 period than prior to 1850. It is assumed here that the 80 percent catch efficiency reflects this lowered productivity.

In Table 9 it is estimated that the total predevelopment run size was about 12.5 to 13 million fish. Because the current run size is about 2.5 million fish, the total loss due to all causes -- hydropower, fishing, logging, mining, irrigation, grazing, urbanization/pollution, and miscellaneous impacts -- can be estimated to be almost 10 million fish, which is within the 7 to 14 million range estimated in Section 2.4, above.

Chapter 3
PREDEVELOPMENT RESOURCE

3.1 INTRODUCTION

3.1.1 Overview

This chapter describes the culture that centered around the Columbia River Basin salmon and steelhead resource prior to major development. By describing that culture, the predevelopment use of salmon and steelhead is described. From that description, estimates of the predevelopment size of runs can be made. To evaluate the losses caused by development, it is necessary to have baseline information on how the fish are distributed, how they are used, and the peoples that relied on them before development and other factors adversely affected the runs. Such development includes hydroelectric, logging, mining, fishing, grazing, and irrigation. This chapter surveys anthropological information regarding the distribution of people and fish, as well as productivity of various stocks of salmon and steelhead in the Columbia Basin.

Although quantitative data are desirable in this effort, such data are increasingly scarce as one moves back in time. Because mainstem dams were not constructed until 1933, there are no pre-1933 data equivalent to modern fish passage records for dams. Similarly, the predevelopment fishery was largely for aboriginal subsistence and, therefore, there are no records comparable to cannery records or other quantitative measures of fish catches. The fact that the primary use of harvested fish was for subsistence of people within the basin does provide a basis for an estimate of aboriginal run size. Additional factors are the size and distribution of the human populations and their daily fish-consumption rate. This estimate can be compared to run sizes recorded after settlement and development of the Columbia River Basin.

To understand the magnitude of the aboriginal salmonid resource, attention must focus first on how these fish were used by the native peoples who once occupied large portions of what is now Washington, Oregon, Idaho, British Columbia, and Montana. Information used to complete the description of resources use includes ethnographic, ethnohistoric and archaeologic data (see 3.2). Using this information, one can determine roughly the magnitude of numerical and cultural losses that have occurred due to elimination or significant reduction of salmon and steelhead available to native peoples. In addition, numerical losses in some specific areas of the basin can be put into perspective. Lastly, by comparing the predevelopment record of aboriginal use of salmon and steelhead with current fish run information, it may be possible to obtain some perspective on the biological loss that has occurred. The predevelopment description of the resource is presented to allow the Council to consider such information in making equitable decisions on establishing goals.

3.1.2 Summary

Columbia Basin salmon and steelhead were relied upon not only for immediate consumption, but were stored for winter subsistence. Only in highly productive root collecting grounds or camas prairies were there good alternatives to salmonids as seasonally abundant resources that could be preserved efficiently in quantity. For some groups, fresh, smoked, or dried salmon apparently dominated the diet throughout the year. For other groups (e.g., Kalapuyans), salmon consumption was probably restricted mainly to immediate use while fresh. Owing to differences in humidity, precipitation, and possibly in the oil content of fish, smoking was the dominant storage technique west of the Cascade Range, while air-drying dominated in the east. In general, fish with high oil content were preferred for eating fresh while those with low oil content were favored for storage.

Unlike the concentrated Euroamerican commercial fisheries that developed in the last half of the 19th century, the Indian fisheries prior to 1850 were dispersed over countless miles of rivers, streams, and creeks within the Columbia watershed. The quantitative importance of salmonids in aboriginal subsistence varied significantly from area to area within the Columbia drainage, but there was probably some dependence upon salmon in virtually all areas of the basin that provided accessible spawning habitat. When all the human populations scattered over the Columbia drainage are considered, estimates of the total yearly catch of anadromous salmonids are impressively high.

After the introduction of the horse in the early 1700s, increased mobility offered alternatives to fishing in and near a group's own territory. This was especially true in those areas east of the Cascades -- what anthropologists refer to as the Columbia Plateau. By traveling to prime fishing locations, natives could intercept fish where the runs were more reliable and the fish were in better condition. Groups that occupied areas beyond the range of anadromous fish could travel to fisheries in other groups' territories, either to fish for themselves or to trade for fish. Ownership of large herds of horses greatly expanded the capacity to transport bulk goods, such as dried fish, over considerable distances. Prior to the horse, similar capacities for transport were limited to those areas of the watershed where water transport could be used.

Fishing technology was diverse and sophisticated. The techniques natives used in various areas depended primarily on the nature of the stream channels. At points where the channel narrowed or natural waterfalls occurred, aggregations of fish allowed easy harvest with dip nets. On the lower Columbia, more complex fishing devices were required. Some, such as seines up to 600 feet long, required several men to operate.

Based upon the data examined, there do not appear to be any major discrepancies between the reports by Fulton on the general distribution of salmonid species within the Columbia Basin (1968; 1970) and the biological, ethnographic and historical data considered here. Salmon and steelhead generally inhabited the entire Columbia River Basin up to the Arrow Lakes in Canada and below the Shoshone Falls on the Snake. Any significant changes in range prior to 1850 probably would have resulted from hydrological changes caused by landslides or tectonic activity that could create or remove obstacles to salmonid migration.

Total catch estimates for Indians in the Columbia Basin have been calculated using aboriginal population estimates and salmonid consumption estimates per capita. Three different estimates of the total annual salmonid catch in the basin have been discussed and range from a low of 18 million pounds (Craig and Hacker 1940) to a high of nearly 42 million pounds (approximately 4.5 to 5.6 million fish). Hewes (1947) reports an intermediate figure of about 22 million pounds, based on assumptions very similar to those of Craig and Hacker. All of these estimates may be conservative because they exclude some other aboriginal uses of fish.

3.2 DATA SOURCES

Three kinds of data are useful in investigating the distribution and abundance of salmonids prior to major development in the Columbia drainage: 1) ethnographic data -- or the studies of living informants by anthropologists; 2) ethnohistoric data -- the accounts of early explorers, fur traders, and others untrained in anthropology; and 3) archaeological data -- the study of material remains.

Ethnographic data for this region were generally obtained from elderly Indian informants whose personal experiences extended back to the early 1800s. This type of information is often integrated with the written records of early Euroamerican observers of native cultures. Most of the ethnographic studies attempt to reconstruct aboriginal cultures as they existed immediately prior to major impacts resulting from Euroamerican contact, such as disease epidemics. The first major disease epidemic is thought to have passed through the Columbia Basin about 1775 (Boyd 1985).

The Northwest Indian groups referred to as "tribes" by ethnographers were distinguished mainly on the basis of linguistics. These tribes rarely possessed any political unity, but instead were collections of independently organized bands or local groups -- people who lived and subsisted together in the same village or camp during a portion of the yearly economic cycle. Because resource use often varied highly among bands within a tribe, the best ethnographic accounts are those that provide detail about individual bands rather than statements about typical behavior for all the bands in a tribe.

Ethnohistoric sources often amount to day-to-day descriptions by Euroamericans of particular events and behavior. These accounts can be quite valuable for their detail. Ethnohistoric descriptions of aboriginal life often tend to be more specific than ethnographies of this region and can be used to crosscheck the latter.

Archaeological data are uniquely valuable for extending the time scale of human resource use into the distant past -- in this instance, back 10,000 years or more. This data source is best suited to investigating how aboriginal cultures evolved and how various food resources changed in importance over time. The archaeological data offer a source of information on how long humans have been using salmonid resources and where. At present, detailed information that would permit identification of prehistoric distributions of the various fish species throughout the basin is very limited. While archaeological data would offer the most direct physical evidence of former salmonid distributions, the potential of these data generally has not been realized. Research currently in progress may overcome this obstacle by developing ways to discriminate salmonid bones commonly recovered, and by improving recovery procedures.

For the purposes of this compilation, we must rely primarily upon the ethnographic sources -- the native informants studied by anthropologists. The ethnohistoric sources are used on a more limited basis because comprehensive treatment of this very extensive literature would be impossible without spending considerably more time. Archaeological data are used mainly to provide a background for more recent data from ethnographic sources.

In focusing on the distribution and abundance of the salmon and steelhead resources prior to major development, this chapter uses anthropological data pertaining to specific areas and places. The aboriginal or "tribal" groupings referred to in this analysis cannot be directly equated with modern groupings or tribal organizations. How modern tribal organizations trace their ancestry back to the peoples observed in the early 19th century is a subject of considerable historical and social interest; it is not, however, essential to the use of anthropological sources for the biological purposes of this report.

Because most of the ethnographic studies aim at reconstructing traditional aboriginal culture prior to Euroamerican contact, these studies generally adopt a time reference of between 1780 and 1800. In the following section it will be suggested that, contrary to popular belief, Indian cultures of the Columbia Basin in the early 1800s had changed considerably over the previous centuries.

The Pacific Northwest includes three distinctive natural and cultural regions that anthropologists refer to as "culture areas:" the Northwest Coast, the Columbia-Fraser Plateau and the Great Basin. The Columbia River Basin encompasses portions of each of these three culture areas. West of the Cascades, the Columbia Basin lies within the Northwest Coast culture area, which was noted for the importance of both riverine and marine food resources in native subsistence. East of the Cascades, the Columbia flows through the Columbia-Fraser Plateau, a culture area distinguished by the economic importance of salmon, roots, and large game. The southeastern portion of the Columbia Basin cuts through the northern part of the Great Basin, a culture area known for the economic importance of seeds and small game.

Although culture areas can be broadly characterized in this way, the importance of different foods varied from group to group within each area. For example, some groups that lived on tributaries of the lower Columbia in the Northwest Coast area depended relatively little upon salmon or marine resources. Other tribes, such as the Shoshoni on the upper Snake River within the Great Basin, relied more on fishing, bison hunting, and root digging than on seed collecting or small game hunting.

Substantial variations in native subsistence occurred even between groups within the same tribe. These tribes often extended over thousands of square miles and included many individual groups, bands, or villages that were self-sufficient. Given the high relief of the mountainous Northwest, it is understandable that profound variations in food resources over relatively small distances contributed frequently to equally profound variations in aboriginal subsistence.

Go To Next Part

Go To Next Part

A significant dependence upon salmon is the single feature that most of the aboriginal groups in the Columbia River Basin shared. Because of their high population densities, complex social organization, large villages, and other features ordinarily found only among agricultural people, the Northwest fishing societies have attracted the attention of anthropologists around the world. The economic importance of salmon is usually recognized as the key factor that accounts for the unusual characteristics of these cultures. Although salmon productivity varied greatly within the individual territories, some even void of salmon, inter-group trade made salmon available to virtually all inhabitants of the Columbia Basin.

For most of the Columbia Basin peoples, salmon were of considerable importance in non-economic ways as well. The annual salmon runs were accompanied by religious rituals and ceremonial rites such as the First Salmon Ceremony, believed to ensure the continued return of the salmon. The salmon also played an important role in Indian folklore, art, music, and mythology. The timing and distribution of the runs were major determinants of yearly patterns of group movement, the organization of households, the division of labor, the size of local groups, and the nature of social interactions among groups. Although the cultural value of the salmon to the Columbia Basin Indians cannot be quantified or adequately characterized, undoubtedly much of what is distinctive about the aboriginal cultures can be attributed to their relationship to the salmon.

The following section presents a brief chronology of salmonid use in the Columbia Basin over the last 10,000 years (Figure 4). The discussion begins with an overview of the archaeological evidence of fish use in the Columbia Basin and a cursory examination of the cultural changes that occurred immediately before and after Euroamerican contact. Following this discussion, anthropological data pertaining to aboriginal salmonid use is examined for seven major subbasins. Estimates of the total aboriginal catch in the early 19th century are then presented, followed by a final discussion and summary.

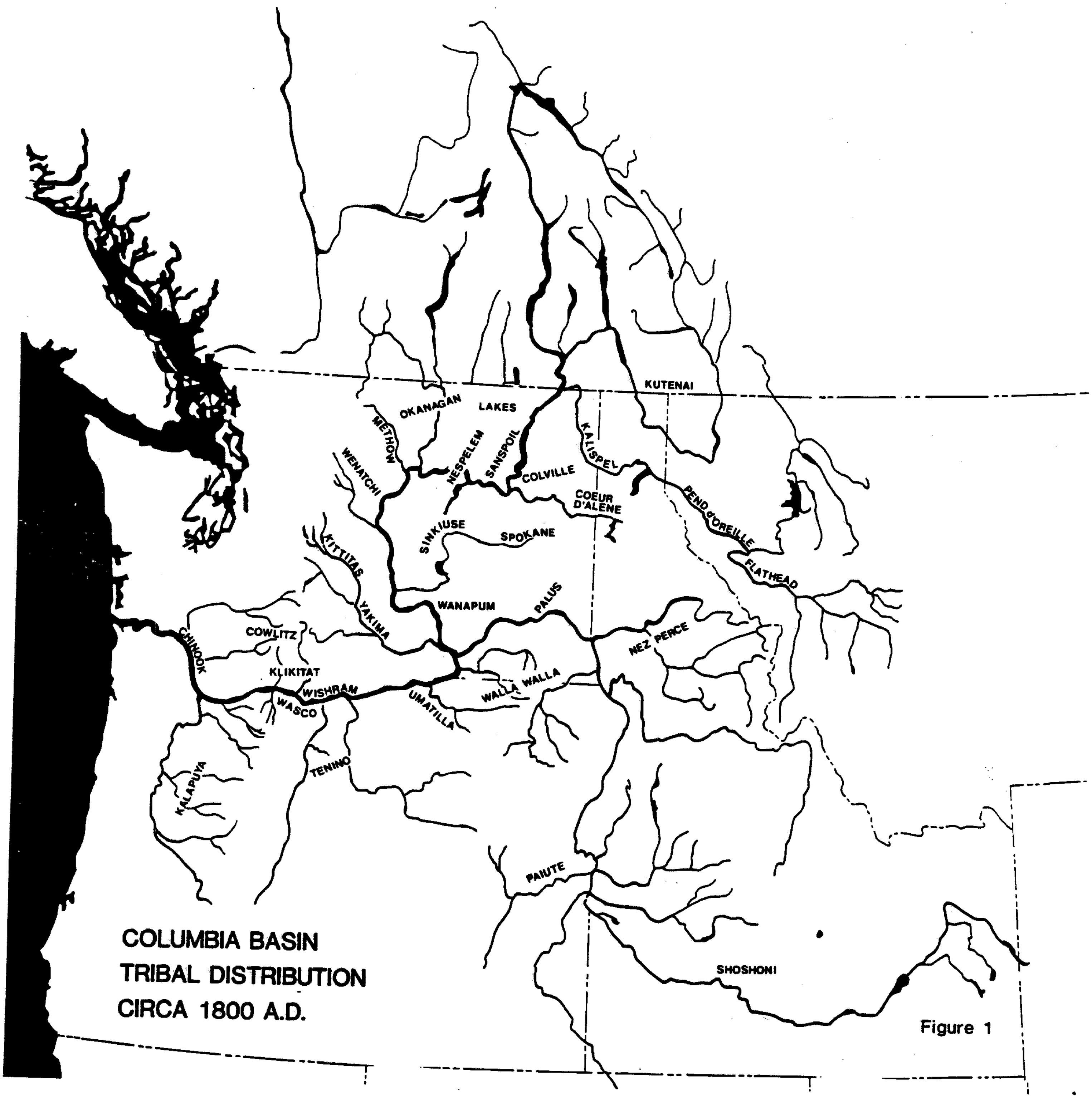

Figure 4. Approximate locations of the various tribal groups at the beginning of the 19th century.

3.3 ABORIGINAL USE OF FISH

The earliest evidence of human use of salmon in the Columbia drainage comes from the Roadcut site at the head of the Long Narrows of the Columbia near The Dalles (Cressman 1960). More than 125,000 salmon vertebrae were recovered from 10,000-year-old deposits. Found with these fish bones were large numbers of stone and bone tools and a wide variety of mammal and bird bones. Salmonid bones also have been recovered from deposits dating between 7,000 and 9,000 years of age at Kettle Falls on the Upper Columbia (David Chance, personal communication). Although preservation of fish bone in such old sites is not often good, several other sites in the Columbia drainage have produced salmonid bones dating between five and nine millenia in age. Salmonids were undoubtedly taken seasonally during this early period, but there is no evidence of drying and storage of these fish as a winter food supply.

Around 5,000 years ago, the first semisubterranean houses or "pithouses" appeared at various locations on the Upper Columbia and Snake rivers (Ames and Marshall 1981). These houses are thought to have been occupied for several months during the winter and, therefore, appear to represent a more sedentary lifestyle than that 5,000-10,000 years ago. The use of stored foods, especially salmon and roots, seems to account for a more settled existence. Food storage is particularly important to understanding the extent of salmon use because storage extends use from a few months to virtually the entire year.

While the relative importance of fish and roots as stored foods is not well understood for the interval between 5,000 and 3,000 years ago, there is strong evidence for increasing dependence upon salmonids beginning 3,000 years ago. Population growth, climatic change, and technological change have been proposed as causes for this growing dependence upon salmon over large areas of the Columbia drainage. It is clear, too, that these changes varied considerably from area to area within the Columbia Basin -- a reflection of the major environmental differences that exist within the region.

The arrival of Spanish horses in the Columbia Plateau during the early 1700s set in motion a number of changes that carried well into the 19th century. Horses had a profound effect on subsistence, trade, travel, and group size over large areas of the Columbia Basin. These effects were greatest in the eastern portion of the basin as habitat requirements of horses confined their distribution to areas that were not densely forested.

Following closely upon the heels of the horse came guns and epidemics of smallpox and other diseases. When the first such diseases arrived is not known, but they can be traced at least as far back as 1782 (Mooney 1928). Recent research suggests a date of around 1775 for the first smallpox epidemic (Boyd 1985). It is clear that after 1825 the decline in aboriginal populations was drastic.

The first Euroamericans to explore and describe this region were members of the Lewis and Clark expedition in 1805-6. By 1810, the fur trade began in the region and continued until 1840 when numerous white immigrants began to settle the area.

In short, most aboriginal cultures of the Columbia Basin were in the midst of dramatic cultural changes decades before changes were observed and described by Euroamericans. These facts in no way diminish the relevance of the anthropological records, but rather offer guidance as to their appropriate use.

3.3.1 <u>The Cowlitz and Lewis River Basins</u>

The basins of the Cowlitz, Lewis and Kalama rivers were occupied primarily by the Cowlitz Indians. Chinook groups occupied the lower few miles of each of these rivers prior to 1830, but since their focus was upon the mainstem of the Columbia they will be discussed below in the Lower Columbia Basin section. The territory of the Cowlitz expanded into these areas and gained frontage on the Columbia, itself, after severe Chinook casualties from smallpox and especially malaria.

The malaria began its devastation in the lower Columbia River Valley in 1830 (Cook 1955). At about the same time, areas previously held by the Cowlitz in the headwaters of the Cispus and Lewis rivers were taken over by

Klickitat from east of the Cascades (Ray 1966). Prior to 1830, the Cowlitz Indians did not occupy prime fishing locales. With the exception of those groups on the Cowlitz below Cowlitz Falls and on the Kalama River, dependence upon salmon was not great. According to Ray (1966):

> The rivers of the Cowlitz were rather small and were relatively unproductive of salmon. The lower courses of the Lewis and Kalama rivers provided quite good fishing sites and the falls of the Cowlitz produced a good many salmon. However, the long course of the Cowlitz, which ran from source to mouth through Cowlitz territory, was one of the meagerest producers of salmon per mile of any comparable tributary of the Columbia. (Salmon were important to the Cowlitz, to the point that they bought many from other tribes, but they occupied a smaller place in their economy than, quite probably, for any other western Washington tribe.)

The Wilkes expedition (quoted in Ray 1966) reported Chinook Indians taking salmon to trade with the Cowlitz:

> On our way [down the Cowlitz River] we met with many canoes passing up, loaded with salmon and trout, which had been taken at Willamette Falls, and which they were then carrying to trade with the [Cowlitz] Indians for the cammas-[sic] root.

Ray (1966) refers to the Cowlitz as a "prairie-oriented" people who, as highly mobile equestrians, were exceptional among the Indians of southwestern Washington. They depended primarily upon hunting, but also extensively used roots. The Wilkes Expedition was one of several early sources that commented on the limited productivity of the Cowlitz River salmon runs:

> There are four different kinds of salmon, which frequent this river [the Columbia] in different months: the latest appears in October, and is the only kind that frequents the Cowlitz River. The finest sort is a dark silvery fish, of large size three or four feet long, and weighing forty or fifty pounds. (Wilkes 1852)

George Simpson (quoted in Ray 1966) lent further support to the preceding in his observation that the Cowlitz River had a fall run of salmon, but none in the spring.

A final indication that the runs of the Cowlitz may have been less productive or dependable relative to those of other rivers within the Lower Columbia is suggested by Commissioner of Indian Affairs M. T. Simmons in 1858 (quoted in Ray 1966):

> The "Stick" Indians [those who live in the forested uplands, including the Upper Cowlitz and the Lewis River Cowlitz Taitnapams] ... do hunt and get deer, elk and bear in considerable quantities; they also plant more potatoes than the others. Roots and berries form an important item with them, and generally there are quantities of both; but when the salmon fail to run, as was the case last fall, the starvation is terrible.

Despite the apparent corroboration of the limited productivity of the Cowlitz in several different historical sources, the more recent historical data from fisheries biology reveals no such pattern (c.f. Fulton 1968; 1970). Why such a contradiction exists remains unexplainable.

3.3.2 <u>The Willamette Basin</u>

There were two aboriginal groupings that occupied the Willamette Basin in the early 19th century: 1) the Clackamas, below Willamette Falls at Oregon City, and 2) the Kalapuya, who occupied the entire basin above the falls. A third group, the Molala, apparently moved into this area between 1810 and 1820 from east of the Cascades (Ray 1938). Hewes (1947) states that "Salmon were undoubtedly the staple food on the Clackamas River, and possibly of the Tualatin."

As with the Chinook Indians of the Lower Columbia, the inhabitants of the Willamette Valley were devastated by disease in the early 1800s, particularly by the malaria outbreak of 1830-1833 (Cook 1955). Ethnographic data pertaining to the Clackamas and Kalapuyan subsistence are therefore scanty.

There are conflicting accounts about whether the Willamette Falls at Oregon City were barriers to fish migration. There are early statements that suggest salmonids were in fact blocked from the Willamette Valley. Alexander Henry, whose fur trading activities brought him to the falls in January of 1814, stated:

> The salmon do not ascend these falls, the rocks being too high and the drop too steep. (Coues 1897)

Alexander Ross (1859) commented:

> To this place and no farther the Salmon ascend, and during the summer months they are caught in great quantities. At this place, therefore, all the Indians throughout the surrounding country assemble, gamble, and gormandize for months together.

Ross' comments seem consistent with Alexander Henry's observations of the Indians above the Willamette Falls in 1814:

> This [Kalapuyan] nation is numerous, extending up to the headwaters of the Willamette, and dividing into several distinct tribes. They are a wandering race, who have neither horses, tents, nor homes, but live in the open air in fine weather, and under the shelter of large spreading pines and cedars during foul weather. Their country is well adapted to such a roving life as they lead, and their wants are few; deer are numerous, but roots of various kinds, which abound, constitute their principal food. (Coues 1897)

The failure in this context to mention salmonids in particular, or fish in general, may be significant. However, Lewis and Clark, on April 9, 1806, noted that groups of Chinook Indians were moving up to fishing stations at the Willamette (Thwaites 1905). In May of 1841, Capital Wilkes described the fishery at the falls of the Willamette:

> At the time of our visit to the falls of the Willamette, the salmon fishery was at its height, and was to us a novel as well as an amusing scene. The salmon leap the fall; and it would be inconceivable, if not actually witnessed, how they can force themselves up, and after a leap of from ten to twelve feet retain strength enough to stem the force of the water above. About one in ten of those who jumped, would succeed in getting by ... I never saw so many fish collected together before; and the Indians are constantly employed in taking them ... The mode of using the net is peculiar: they throw it into the foam as far up the stream as they can reach, and it being then quickly carried down, the fish who are running up in a contrary direction are caught. Sometimes twenty large fish are taken by a single person in an hour; and it is only surprising that twice as many should not be caught. (Wilkes 1852)

Further historical evidence for the existence of spring/early summer runs of salmon above the Willamette Falls is the fact that in 1829 the Hudson's Bay

Company established a facility at the falls because it was a major gathering place for the Indians. In 1841, 800 barrels of salmon are reported to have been purchased from the Indians by the Hudson's Bay Company (Craig and Hacker 1940).

Although the preceding passages seem contradictory, the matter can be reconciled. The vertical drop at Willamette Falls is almost certainly too great for fish to jump during stages of low water, which prevail during the late summer through winter. During the annual freshet, however, this vertical drop could be significantly reduced by a combination of the increased volume of water coming over the falls and higher water below. Salmonid runs, such as the spring chinook and steelhead runs, apparently passed the falls, but fall runs of chinook and coho did not.

The historical evidence indicates that the Willamette Falls were an important spring fishing site for the Clackamas Indians and probably other groups as well. The silence of the historical record regarding any fall fishery at the falls may be significant.

The lack of fall runs partially explains why the aboriginal inhabitants of the Willamette Valley above the falls were not known for their reliance upon salmonids. The fall runs generally were preferred by native peoples of the Northwest for drying or smoking for the winter season (Schalk 1984). The spring/early summer runs are not only high in oil content, but their arrival coincides with the onset of the warmest months of the year. Both of these conditions are likely to have discouraged dependence upon spring run salmonids for storage purposes, although these fat fish would have been superior for fresh consumption.

The pre-1850s distribution of the salmonid resources within the Willamette Basin is not a subject on which the ethnographic literature is likely to shed much new light. From a biological perspective, it is likely that the eastern tributaries of the Willamette Valley would have provided suitable spawning for spring/early summer chinook. These rivers, in contrast to the valley's western streams, draw tribute from high elevation snowfields in the Cascades and have sufficient flow in late summer and fall. The concentration of spring and summer chinook habitat in the upper portions of the Willamette Valley's east side drainage is clearly evident in Fulton's analysis of biological data (1968 Map 1). Kalapuyan use of salmon, however, was apparently not constrained to those runs that could ascend the Willamette Falls during the spring freshet. They are reported to have traded for salmon and lamprey at the falls (c.f. Henry 1898), but may also have had some villages located below the falls (Ross 1859).

Because the Clackamas River enters the Willamette below the falls, this drainage supported spring as well as fall runs of salmon. Information on the yearly economic cycle for the Clackamas Indians is scarce, but Woodward (1974; cited in Boyd 1985) reported that they concentrated at Willamette Falls and the mouth of the Clackamas for the spring chinook runs.

3.3.3 The Lower Columbia Basin

The Lower Columbia Basin consists of the mainstem Columbia from its mouth to the Columbia-Snake confluence, including all tributaries that enter along that reach except the Cowlitz, Lewis, and Willamette. So defined, this basin cross-cuts a major natural and cultural boundary between the dry sagebrush steppe of the Plateau and the dense forest downstream from The Dalles. Centered about the vicinity of The Dalles was the boundary between two major language families -- Chinookan and Sahaptin. The Chinook-speaking groups dominated both banks of the lower river and, from saltwater upstream to The Dalles, consisted of the Lower Chinook or Chinook proper tribe, the Kathlamet, the Clackamas, the Cascades, Hood River, White Salmon, Wishram and Wasco tribes. Adjoining the Lower Chinook were two Atabaskan groups -- the Owilapah, or Kwalhiokwa, and the Tlatskanai.

There are no details regarding the use of fish by these groups. For the Lower Chinook and the Wishram, there are ethnographic studies, but only the ethnohistoric accounts for the intermediate Chinookan groups. There can be little doubt that these intermediate groups depended heavily upon salmonids for their subsistence.

Moving upstream along the Columbia from The Dalles, the Sahaptin groups in this subbasin included the Tenino, Umatilla, Cayuse and Walla Walla Indians. Ethnographic materials for these groups are relatively scanty. Anastasio's (1972) analysis of intergroup relations for the Southern Columbia Plateau probably provides the single best overview of these groups. Because many groups had village sites and fishing stations along the Columbia mainstem, where they were frequently observed by river travelers, the ethnohistoric literature is rather extensive. The journals of Lewis and Clark along the Columbia (Thwaites 1905) are especially informative regarding the intensity of fishing along the Columbia that they observed in the fall of 1805 from the mouth of the Snake to the western boundary of Sahaptin country near The Dalles.

Although the Sahaptin groups had horses, their economy remained strongly oriented towards fishing. The influence of the horse probably increased the volume of dried fish traded to groups in other areas. This region is dominated by sagebrush steppe and is less productive for game and plant resources than other areas of the basin. People living in this area probably depended upon anadromous fish more than many groups in portions of the Columbia Basin where fish, game, and root resources were more evenly available.

The density of archaeological sites dating to the last 2,000 years along the Middle Columbia is high compared to upstream locations within the basin (Osborn 1957). The largest prehistoric village sites that have been documented in the Columbia Basin occur in this general area (Schalk 1984). The importance of salmonids in the subsistence of the prehistoric inhabitants of this area has been emphasized in archaeological studies of pithouse village sites (Osborne 1957; Schalk 1984).

3.3.3.1 The Lower Chinook Indians

Around 1800, the Lower Chinook occupied Willapa Bay and both banks of the Columbia from the mouth upriver for about 50 miles (Ray 1938). All five species of Pacific salmon were present within the Lower Chinook range. These people were primarily fishermen. In contrast to the salmon diet of people east of the Cascades, non-salmonid freshwater fish and marine mammals, fish, and shellfish complemented salmonids in the Lower Chinook diet, rather than game and roots:

> The salmon was by far the most important fish but other species figured very prominently. Sturgeon (Acipenser transmontanus), a much favored fish, was doubly important because a single catch provided a huge supply of food. The steelhead trout (Salmo gairdneri), classed with the salmon by the natives, was taken in large numbers. The candlefish or eulachon (Thaleichthys pacificus) and the smelt (Spirinchus thaleichthys) were in great demand for the oil they produced. The California herring (Clupea pallasii) and the California sardine (Sardinia caerulea), which were very abundant, were taken in great quantities with the herring rake. (Ray 1938)

On the Lower Columbia tributaries, spearing, dip-netting and weir fishing techniques were used. On the Columbia itself, hemp or spruce root seines were the most productive of the fishing techniques employed; these varied from 100 to 600 feet in length and 7 to 16 feet in width. Seining provided a means for taking salmonids in large numbers where no natural channel constrictions existed. The grooved stone net-weights that have eroded out of archaeological sites between Astoria, Oregon, and Bonneville Dam provide evidence of the former importance of seining on the Lower Columbia.

3.3.3.2 The Wishram and Wasco Indians

These two Chinookan-speaking groups centered around the major rapids at the head of the Columbia Gorge, or what has also been called The Long Narrows. The Wishram resided on the north side between White Salmon River and Ten-Mile Rapids. The Wasco occupied the south side between Ten-Mile Rapids and the mouth of the Deschutes River.

Owing to tremendous basalt bedrock constrictions of the Columbia's channel for several miles, this general area was one of the best fishing locations on the entire Columbia. Due to an ideal combination of proximity to the ocean and dry, windy climatic conditions that made fish-drying easy, the area from the Long Narrows to Celilo Falls may have also been the most productive aboriginal fishery in the world. During the early 19th century and probably for centuries before, this area was a great trade center where

Indians from other regions came to trade, gamble, and fish (Spier and Sapir 1930). Alexander Ross (1904) reported that 3,000 or more Indians would gather at the upper end of the Long Narrows during the fishing season, but that permanent residents numbered about 100.

Dip netting and spearing were exceptionally important fishing techniques at the Long Narrows. Two-man seines 100 feet long and 12 feet deep were used in some places (Spier and Sapir 1930). Basket traps and weirs were used as well.

Large quantities of dried salmon were pounded into "pemmican" for winter provisions and for trading with tribes to the east and west (Thwaites 1905). Farther down river at The Dalles, Clark observed 107 of these stacks of pounded fish estimated to contain "10,000 lb of neet fish" (Thwaites 1905). In the fall of 1805 at The Dalles, Lewis and Clark observed great numbers of fish-skin lined baskets of pounded fish cached on islands in the Columbia (Thwaites 1905). The pounded fish in these baskets were packed so hard that a single basket two feet long and a foot in diameter weighed between 90 and 100 pounds. According to their owners, these caches were destined for trade. Quantities of dried fish also occupied half the space inside of the Indian houses that were visited (Thwaites 1905). In late October, the fishing season was just coming to a close and large quantities of dried fish were everywhere. Using quantitative information provided by Lewis and Clark, Griswold (1953) estimated that 1 million pounds of pounded salmon were prepared at The Dalles just for trade in the early 1800s.

3.3.3.3 The Tenino Indians

The Tenino Indians occupied the Oregon side of the Columbia from Ten-Mile Rapids near The Dalles upstream beyond the mouth of the John Day River. They also occupied the lower reaches of the John Day and Deschutes rivers. There were four subdivisions of the Tenino: 1) the Tenino proper, who fished east of The Dalles; 2) the Wayam, who fished at Celilo Falls; 3) the John Day, who fished along the lower John Day River and the adjacent sections of the Columbia east to Arlington; and 4) the Tygh, who fished at Sherar's Bridge on the Deschutes (Murdock 1938). Drawing upon unpublished ethnographic data collected by Murdock, Hewes states:

> Tenino fishing is fairly well known from the work of Murdock. Fish were the basic food sources, bulking larger than either game or wild vegetable foods. Salmon was the staple, supplemented by steelhead, which were present the year round in the Columbia. Salmon runs began in late April, with a late summer run extending into October. During the salmon season, about half the Tenino were established in fishing camps. Despite the much greater productivity of the main river to the north [Columbia], both the John Day and Deschutes Rivers had salmon fisheries of considerable importance. The falls of the Deschutes at Sherar's Bridge about 35 miles above the Columbia were visited in 1826 by Ogden, who found a camp of twenty families fishing there for salmon, using dip-nets and single-toggle harpoons. In March there was a special mass fishing for steelhead in the lower John Day River. (Hewes 1947:104-5)

Celilo Falls, the principal fishing site of the Wayam subdivision of the Tenino, have been described as "by far the most productive inland fishing site in native North America" (Hewes 1947). Salmon were taken here from the beginning of May through the end of October (Thwaites 1905). This location was exceptionally important during the fall fishing season when low water exposed many excellent fishing sites. A member of the Astoria party related that as many as 500 fish might be caught per day by an experienced dip net fisherman (Writers Project 1940; cited in Hewes 1947). In addition to the dip nets and single-pronged spears used at places like Celilo, Tenino fishing equipment also included 30-foot-long nets used from canoes (Hewes 1947).

3.3.3.4 <u>The Umatilla and Walla Walla Indians</u>

Umatilla fishing areas extended along the Columbia from Alderdale, Washington, to the vicinity where the Oregon-Washington boundary intersects the Columbia River. There were also villages and fishing sites along the lower Umatilla River. The journals of Lewis and Clark (Thwaites 1905) provide accounts of the people and activities observed between the mouth of the Snake and The Dalles in the fall of 1805 and again in the spring of 1806. On the journey downriver, a total of 34 Indian villages were observed. People were "gigging" and drying salmon along this entire stretch. Use of the spearing technique suggests the possibility that fall chinook were being taken while spawning on gravels in the Columbia itself. On the return trip upriver in the spring, only 11 villages were observed in this same stretch, but one near the mouth of the Umatilla River contained 700 people. These people were anxiously awaiting the arrival of the spring salmon runs, which were expected within a few days.

The Walla Walla or Walula Indians occupied the lower Walla Walla River and the Columbia from below the mouth of the Walla Walla to above the mouth of the Snake. Very large groups, in excess of a thousand, are described for this area in the early 19th century. They gathered at rendezvous locations at the mouths of the Walla Walla and Snake rivers. Combined camps of Walla Walla and Cayuse are mentioned frequently in early 19th century accounts. The area was also used by Yakima and Palus Indians (Ross 1859).

3.3.4 The Yakima Basin

Very little ethnographic information exists on the aboriginal occupants of the Yakima Basin in the early 19th century. The Sahaptin-speaking Yakima occupied areas between the mouth of the Yakima River and Kittitas Creek. Another Sahaptin group, the Kittitas, resided upstream from the Yakima within the basin.

The Kittitas are reported to have been primarly dependent upon salmon, despite their location at the headwaters of the Yakima River (Hewes 1947). This may be related partially to the fact that there were lakes that supported spawning populations of sockeye in this area (Fulton 1980). Ray (1936) reported that historically a "huge salmon trap was maintained" at the outlet to Cle Elum Lake and that during June and July as many as 1,000 people would gather there.

Curtis (1911) provides brief descriptions of the Yakima subsistence cycle:

> In the early spring they repaired to the fisheries in the larger river, and fishing, hunting, and root-digging continued until midsummer, when they moved into the mountains to gather berries. As autumn approached they returned to the valley for the late fishing, which continued until cold weather forced them into winter quarters. (Curtis 1911)

The "larger river" referred to here could be either the Yakima or the Columbia in the vicinity of the Yakima and Snake confluences. Salmon and roots were listed as the "principal foods" for the Yakima (Curtis 1911). Hewes (1947) reported that salmon were the "chief food" of the Yakima, but that they "occupied a less favorable area for fishing;" he does not offer the basis for such a conclusion. Dried fish, according to Curtis (1911), were obtained through trade with Columbia River groups, and this may imply that demand exceeded supplies locally.

3.3.5 The Middle Columbia Basin

The Middle Columbia Basin is defined as the mainstem Columbia from the mouth of the Snake to Chief Joseph Dam, including all tributaries except for the Yakima River. As with the Lower Columbia Basin, the Middle Columbia Basin cross-cuts a major Indian language boundary near Priest Rapids -- the boundary between Sahaptin speakers to the south and Salish speakers to the north.

From the mouth of the Snake to Wenatchee, the Columbia passes through the driest part of the Columbia Basin. From Wenatchee north, the Columbia borders forest to the west and the steppe to the east. Upriver, the tribal groupings in the Middle Columbia Basin consisted of the Wanapam, Columbia, Wenatchi, Entiat, Chelan, Methow, and Okanagon. The early fur traders and explorers, while frequently passing through this area, provided few details about its aboriginal occupants (Ray 1974). Some of the groups (e.g., the Wanapam and Wenatchi) depended mainly on salmon fishing while others apparently made only limited use of salmon (e.g., the Chelan and Columbia).

3.3.5.1 The Columbia Indians

The territory of the Columbia tribe, like that of the Wanapam, included no salmon-producing tributaries to the Columbia River itself. In an in-depth analysis of the major historical sources on this group, Smith (1983) concluded that salmon were probably of limited importance to all but a small portion of this tribe. Instead of spending their summers along the Columbia River fishing, these groups moved away from the river and dispersed for root collecting (Smith 1983).

3.3.5.2 The Wenatchi and Entiat Indians

Also known as the Pisquows, the Wenatchi occupied the Wenatchee River Valley as well as the Columbia above and below the mouth of the Wenatchee River. Numerous fishing stations were reported on the Columbia and Wenatchee rivers (Ray 1974). Several hundred people gathered at the mouth of Icicle Creek (near Leavenworth, Washington), the Wenatchi's principal fishery, for the peak of the summer salmon fishing season. Salmon were dried here on communal racks prior to transport to winter villages.

Smith (1983) described the Wenatchi as being distinctly river-oriented compared to other Middle Columbia groups. Winter villages were located primarily along the Columbia, but a third of the Wenatchi population was said to have wintered on the Wenatchee River.

The Entiat Indians were located at the mouth of Entiat River and were often included with the Wenatchi. Ray (1974) stated that the Entiat was "a river of modest importance." Smith (1983) suggested that these people may have depended largely upon salmon fishing and that they lived on the Columbia River both summer and winter.

3.3.5.3 The Okanagon, Southern Okanagon or Sinkaietk Indians

The Okanagon territory included the entire drainage of the Okanogan and Similkameen rivers as well as the Upper Methow River. Teit (1930) distinguished two divisions of the Okanagon: 1) the upper Okanagon, who resided on Okanogan, Long, and Dog lakes; and 2) the lower Okanagon, who resided on the Okanogan River below. He estimated that there were about 18 winter villages of Okanagon "at one time" (Teit 1930). These people had only limited numbers of horses, which were introduced early in the 18th century (Teit 1930), but not until 1840 or so, according to Post (1938).

Post (1938) stated there were two main seasons in the yearly cycle of the Southern Okanogon -- the sedentary period from about mid-November to early April, during which stored fish and roots were consumed, and the rest of the year, during which the various resources were exploited from numerous camps.

Regarding the species of salmon present in the Okanogan, Post (1938) stated:

> Of the five species of salmon frequenting the Northwest Coast, evidence was found in the Okanogan River of three: (1) Oncorhynchus tschawytscha, or Chinook salmon, which ran in May, June and July in the headwaters of the Columbia. They are by far the most abundant, now as formerly, and run for the longest period. [According to Koch (1976), however, sockeye was the major species in the Okanogan River.] They rarely went higher than Oroville. They begin spawning in the lower Okanogan in mid-September.... (2) O. nerka, the blueback or sockeye salmon, which run in July and August according to Cobb, in late May and June according to the local game warden. (3) O. kisutch, silver or white salmon, taken in November.
>
> The steelhead trout, usually thought of as salmon, were fully as important as the last two species. They were taken when they ascended the rivers in March or April. After spawning, they descended the small streams to the Columbia River where by winter time they were fat enough to be worth catching.

In another context, however, Post states that the steelhead run that arrived in the spring (April) "was not so important." This apparently refers to quantity because fishing activity during spring was concentrated on suckers (Post 1938).

After collecting roots in late April and May, the Okanogon turned to the salmon runs, which began in June and extended through October (Post 1938). Plant foods were also collected during the fishing season. The end of the main fishing season in October was followed by deer hunting in late October and early November. Before settling into winter quarters, some families speared "dog salmon" at the confluence of the Okanogan and the Columbia (Post 1938). Post (1938) also alluded to "silver salmon" that apparently were taken in small numbers during winter and dried under the eaves of houses.

Major fishing weir sites were at Monse, a mile downstream from Malott, and a mile below Omak (Post 1938). Traps and spears were used in conjunction with weirs. Teit (1930) identified Okanogan Falls, along with Kettle Falls, as the "chief salmon fishing places" and largest trading centers on the entire upper Columbia.

There is some suggestion that the salmon runs were limited in this area. Spawned-out and dead salmon were collected to be dried for food:

> They had to be eaten "from the pole:" if put away in bags as the fresh ones were when dry, they would be very bad. So they were left hanging all fall and winter, higher than the coyotes would be able to jump, or they would be roasted at once. They always smelled bad, but are said to have tasted good despite the smell. These salmon had no fat, and were very stringy. (Post 1938)

This practice might be interpreted as insurance against shortages in the typically difficult late winter/early spring season. Along these same lines, Teit (1930) observed:

> Many Okanagon from Okanagan Lake and the upper part of Okanagan River, where salmon were scarce, went to fish salmon on the Lower Okanagan River. A few of the Similkameen people went to the Thompson and Nicola to fish.

3.3.6 The Upper Columbia Basin

The Upper Columbia Basin is defined as the entire Columbia watershed upstream from Chief Joseph Dam. Much of this area is forested and several of the major tributaries, such as the Spokane, Pend d'Oreille, and the Kootenai rivers, have falls that block the ascent of anadromous fish. Aboriginal groups within this basin are Salishan speakers except the Kutenai. Moving upstream in order, the tribes are the Nespelem, Sanpoil, Colville, Lakes, Kutenai, Spokan, Coeur d'Alene, Kalispel, Pend d'Oreille, and the Flathead. The groups of this basin were extraordinary in the degree of variation in their subsistence. Some, such as the Colville and Spokan, depended primarily upon salmon fishing while others, such as the Lower Kutenai, fished primarily for resident fish in large lakes. Bison hunting and root collecting, respectively, were the primary pursuits of the Flathead and some Kalispel groups.

3.3.6.1 The Sanpoil and Nespelem Indians

The Sanpoil and Nespelem occupied the Columbia River between Condon's Ferry and the mouth of the Spokane River. Their annual cycle of subsistence began in March, when they moved from their pithouses, which they occupied throughout winter, to collect small game and roots. Within two to three weeks the population moved to root gathering grounds away from the river. In early May, summer fishing began with the appearance of salmon and trout. Traps were placed at the mouths of the Sanpoil, Spokane, and Kettle rivers, as well as other places. By the first of September, the summer fishing season came to a close. Some people placed their dried fish in temporary storage and traveled into the mountains to hunt and collect the fall roots. Other people moved to locations where fall run "silver and dog salmon" were seined or speared from canoes. Due to the drop in temperature, fish were dried indoors with the aid of fire (Ray 1933). In mid-October, the Sanpoil and Nespelem returned to their winter villages where they subsisted on stored foods.

Regarding the species and quantities of salmonids taken by the Sanpoil and Nespelem, Ray (1933) stated:

> Salmon ... and steelhead trout ... were caught in large numbers each summer, a portion to be used as fresh food at the time but the greater percentage to be dried and stored for winter consumption. Of the five species of salmon which frequent the Columbia and its tributaries, all but one reach the portion of the river which flows through the Sanpoil country.

According to Ray (1933), the only species of the five indigenous to North America that did not occur in this region was the sockeye, which "is seldom found farther upstream than the mouth of the Okanogan River, which is below Sanpoil territory." Ray's statement, however, is contradicted by historical evidence for sockeye runs at least as far up the Columbia as Slocan and Arrow lakes in British Columbia (cf. Chapman 1943; Fulton 1970). The confusion on Ray's part regarding sockeye may stem from the behavioral differences between this species and chinook or steelhead. It appears that instead of jumping the falls like these other species, sockeye avoid the main current and move through eddies where they were neither seen nor caught in the basket traps (Washington Department of Fisheries, 1938). Other lakes such as Windermere, Columbia and Whatshan, which were near the very headwaters of the Upper Columbia, probably supported sockeye runs as well (Fulton 1970). The presence of pink salmon in this area of the Columbia is also questionable (Fulton 1970; Butler and Schalk 1984).

Ray's "dog salmon" may not be the chum salmon (Oncorhynchus keta), but fall chinook, which by their lack of oil and relatively poor condition are physically distinct from earlier chinook (Everman 1896; Schalk 1982). The fall chinook run spawned in the mainstem of the Columbia River in this area (Chapman 1943). The fact that Ray does not mention them lends support to the conclusion that "dog salmon" was a popular term for fall run chinook. Further support comes from Sahaptin speakers to the south, who referred to any spawned-out salmon with the same term they used for chum salmon (Hunn 1979). It can be conjectured that the reference to dog salmon simply alluded to the large canines and dog-like appearance of the mature fall chinook salmon or even to how certain fish might be used -- as dog food.

Ray (1933) described the timing of the individual runs:

> Salmon is present in the ... Columbia from May until November. Some are still to be found even later in the winter, but the flesh is hardly edible, due to deterioration after spawning. Steelhead trout run from early March until July.... Following the steelheads is the summer or chinook run of salmon, occurring during May, June and July.... In the fall a double run occurs, bringing the silver and dog salmons. These species appear during the latter part of August or early in September and continue to run through November. The flesh of both remains edible throughout this period. Neither variety is large in size, the average weight for each being about six pounds. The humpback salmon, although present in this region, is present only in negligible quantities.

Spearing salmonids at narrow passages, natural or constructed, was a major fishing technique for the summer runs (Ray 1933). Spearing from canoes was used in the fall, "especially for the white or silver salmon" (Ray 1933). Traps were characterized as far more productive than other techniques used in this area. Ray (1933) reported that many Sanpoil camped at Kettle Falls in Colville, territory during the fishing season; he described this place as "probably the most important fishing site on the Columbia River above The Dalles" (Ray 1933). Weirs and a variety of traps were used by the Sanpoil and Nespelem. Seines were used in the fall when coho and fall chinook probably dominated the catch. "In the fall white salmon and dog salmon were taken in considerable quantities" (Ray 1933). Seines, which apparently were used at night only, were described as being 30-40 feet in length and six feet deep (Ray 1933). Ray (1933) reported that "[a] successful night's seining netted from forty to a hundred salmon."

Salmon were air-dried in the summer, but dried indoors in the fall, where some smoking occurred incidentally. Dried fish were stored in tule bags, which averaged about 100 pounds (Ray 1933).

3.3.6.2 The Colville Indians

Kettle Falls on the Columbia River was one of the most productive and best known Indian fisheries of the Upper Columbia during the early 19th century. Teit (1930) is a primary ethnographic source on the Colville and he reported that the Colville "fished more salmon than any of the other inland tribes of this [the Okanagon] group" -- the Sanpoil, Nespelem, Lakes, and Southern Okanagon (1930). The Colville were accompanied at Kettle Falls by a number of other groups from surrounding areas such as the Lakes and Pend d'Oreille (Curtis 1911, Teit 1928). A substantial amount of fish was apparently prepared here for trade or sale to groups lacking a fishery or not having one of comparable productivity. Kettle Falls, along with Okanogan Falls, were considered the two major trading centers on the Upper Columbia (Teit 1930), even prior to the introduction of the horse (Teit 1930). Teit (1930) reported that the Colville:

> ...procured horses, painted bags and parfleches, buffalo robes, etc., from the Kalispel, in exchange for dried salmon, and some articles reaching them from the west and north, such as shells.

Unlike many of the mounted groups surrounding them, the Colville did not travel to trade because the trade came to them (Teit 1930).

Traps that were used at Kettle Falls were especially renowned for their effectiveness in taking salmon. In 1841, Captain Charles Wilkes (1852) described these basket traps and reported that the Indians frequently took 900 salmon in 24 hours. Assuming a 60-day run and 500 fish per day as an average catch, the annual catch at this one location would have been 600,000 pounds (Craig and Hacker 1940). Chance (1973) discusses a number of other estimates for the catch here including one of 1,000-1,500 fish per day by Jacob Meyers (1912).

3.3.6.3 The Lakes Indians

The Lakes Indians occupied a large area that included the Arrow Lakes, Slocan Lake, and the Columbia Valley above Kettle Falls. Much of their country is forested and relatively moist, not suited for horses (Teit 1930). This fact, and the presence of large lakes, resulted in a primary reliance upon canoes for transportation. In the southern part of Lakes territory, however, a few Lakes people apparently used horses. The villages in the southerly portions of the Lakes territory were larger, but less frequent than in the northerly districts (Teit 1930). These contrasts within the Lakes area undoubtedly reflected variations in habitat (Teit 1930).

Teit (1930) mentioned that important salmon fishing sites existed on the east side of the lower end of Upper Arrow Lake; on a creek opposite Revelstoke; and "at the head of the bight [bend in the shoreline forming an open bay] in Upper Arrow Lake above Arrowhead." According to Teit (1930), the Lakes also fished at locations in the Colville territory; they "went down to near Marcus, Kettle Falls, and other places along the Columbia on the confines of the Columbia." Curtis (1911) stated that the Lakes shared the salmon fishery at Kettle Falls with the Colville from June until the fall.

Although Bonnington Falls on the Kootenai River blocked anadromous fish, Teit (1930) wrote that the confluence of the Slocan and the Kootenai was a "noted fishing place" and that "Salmon were formerly plentiful throughout the Slocan district, and many people lived at all the villages." This vicinity appeared to have been important to the Lower Kutenai, who came here to fish as well:

> In early times some trade was carried on between the Lower Kutenai and the Lake tribe. Parties of the former frequently came to the mouth of the Slocan River, and occasionally to the mouth of the Kootenai, to buy salmon. They left their canoes above Bonnington Falls; and after living a couple of weeks with the Lake tribe, and eating plenty of fresh salmon, they departed, carrying their fish over the portage.... Trade between the Lake tribe and the Kutenai was not increased by introduction of the horse, but rather the reverse was the case. (Teit 1930)

The Lakes are reported to have been "decimated" by an epidemic of smallpox in 1800 and again in 1832. (Teit 1930)

3.3.6.4 The Kutenai Indians

The Kutenai territory comprised a sizeable area of the interior of British Columbia, a corner of northern Idaho, and northwestern Montana. The Kutenai occupied the Kootenai River Valley above Bonnington Falls, which is located a few kilometers downstream from the outlet to Kootenai Lake. They also occupied the headwaters of the Columbia upstream from the vicinity of Golden, British Columbia. Two major divisions were recognized: 1) the Lower Kutenai, who occupied the Kootenai River Basin below Kootenai Falls, and 2) the Upper Kutenai, who occupied the Kootenai River Valley above Kootenai Falls as well as the upper North Fork of the Flathead River.

During the 18th century, most of the Upper Kutenai had horses and depended significantly on bison hunting east of the Rockies (Schaeffer 1940; Turney-High 1941; Smith 1984). The introduction of firearms, encouragement from the fur traders to trap and hunt, and the arrival of the horse were factors that apparently shifted the Upper Kutenai economy from one based mainly upon fishing and hunting to one based more upon hunting (Schaeffer 1940).

The forested habitat of the Lower Kutenai was not suited for horses and these people continued to depend on hunting, fishing for non-anadromous species, and plant collecting. Anadromous fish were not able to ascend Bonnington Falls below Nelson, British Columbia (Turney-High 1941), so they were unavailable within the country of the Lower Kutenai. Although no details are provided, it was reported that the Lower Kutenai shared fishing sites with Lakes below Bonnington Falls near Nelson (Turney-High 1941). Salmon did migrate into Upper Kutenai territory near Columbia and Windermere lakes at the headwaters of the Columbia. The two Kutenai divisions were distinguished in subsistence partially by their relative dependence upon fishing:

> Despite their more westerly habitat and greater dependence on fish, salmon played a smaller role in the economy of the Lower Kutenai than among the Upper bands. Both groups prized

> the great Northwest fish equally, but neither looked upon it as the basic staple of life, as among more westerly tribes. The fact is that while the Lower Kutenai often took salmon at Nelson, they generally met the Upper bands fishing near Windermere.... At that spot the headwaters of the Kootenay [sic] and the Columbia rivers are separated only by a low divide of about two miles width. The salmon spawned in the marshes and sloughes from which this, the main thread of the Columbia, arises. (Turney-High 1941, emphasis added)
>
> Among the Upper Kutenai, except for the spearing of salmon at Columbia Lakes, fishing was largely done to secure change in a diet that otherwise consisted predominately of animal flesh, or during seasons of scarcity, to eke out a scanty food supply. At Tobacco Plains the extent to this activity was a matter of preference among individual families, some of which spent several weeks in salmon fishing on the head waters of the Columbia. Others were content to take fish [non-anadromous] in small quantities irregularly throughout the year. (Schaeffer 1940, emphasis added)

Additional details regarding the timing and abundance of salmon at the source of the Columbia warrant quotation:

> Salmon migrating from the Pacific Ocean to spawn in the headwaters of the Columbia River, provided an important source of food for some families in the Upper Kootenai region. Towards the close of summer certain families travelled northward from Tobacco Plains for the salmon season. The fish began to arrive in this region in August, the run, or runs, continuing until September or October. Often a few families would reach the upper Columbia at the beginning of the migration season and send news to Tobacco Plains on the size of the run. If there were prospects of an abundance of salmon, other groups would hasten north to take part in the catch.
>
> The fishing parties made their first camp near Briscol in August, and after taking salmon there for a time, moved up the Columbia to the fishing site near Fairmont Springs. During August and September the run was usually of some size and of good quality but by October, the fish began to decline both in condition and numbers. The season was closed with a small catch made at the site near Althalmer. (Schaeffer 1940)

David Thompson's journal (1962) provides observations regarding salmon immediately below Windermere Lake. These observations, made in the fall of 1807, represent the earliest written accounts of salmon in this region:

> At length the Salmon made their appearance, and for about three weeks we lived on them. At first they were in tolerable condition, although they had come upwards of twelve hundred miles from the sea, and several weighed twenty five pounds. But as the spawning went on upon a gravel bank a short distance above, they became poor and not eatable. We preferred horse meat.

In August of 1809, Thompson (1962) crossed from the headwaters of the Columbia to the headwaters of the Kootenai River and mentioned spearing "a few tolerably good salmon" in Windermere Lake.

Based upon experiences during his residence in the Canal Flats area in the 1880s, Baillie-Grohman (1907) provided the following account of salmon near the source of the Columbia:

> Forty years ago the number of fish who reach these beds was so great that the receding waters [the freshets from the receding snows cause a considerable rise] would leave millions of dead salmon along the banks, emitting a stench that could be smelt miles off, and which never failed to attract great number of bears.

A final account of salmon in this area is that of Hector on September 17, 1859, of the Palliser Expedition (Spry 1968). Many dead salmon were observed from the mouth of the Blaeberry River up to Windermere and Columbia lakes. In the vicinity of these lakes, he saw two Kutenai families drying salmon taken in Columbia Lake.

Generally, salmon species were not identified in the ethnographic and historical sources pertaining to this area; salmon were referred to in a generic sense. Based upon historical accounts of the season of availability and size of individual fish, the chinook and sockeye salmon may have been represented.

Turney-High (1941) stated that the Kutenai relied entirely on spears for taking salmon. Spears were used from canoes, often by torchlight at night. Storage techniques involved partial sun-drying followed by fire drying; the Kutenai did not pulverize dried salmon (Turney-High 1941). According to Schaeffer (1940) the Kutenai used weirs and nets as well as spears.

Smith (1984) summarized three important characteristics of salmon to the Kutenai -- they were restricted to a small part of the Kutenai territory; they were available for a relatively brief interval of the year (late summer/early fall) compared to most other areas of the Columbia Basin; and they were important in the diet of some Upper Kutenai families. Historical sources suggest that the magnitude of the runs from year to year at the Columbia headwaters was subject to sizeable fluctuations.

3.3.6.5 The Spokan Indians

The Spokan were located on the Spokane River and its tributary, the Little Spokane. The southern portion of their territory extended southward as far as Cow Creek, tributary to the Palouse River (Teit 1930). The Spokan were commonly divided into three groups: 1) the Lower Spokan, on the lower river and around its confluence with the Columbia, 2) the Middle Spokan, who extended upstream to below the mouth of the Little Spokane, and 3) the Upper Spokan, who occupied the Little Spokane River Valley and the Spokane River below Spokane Falls (Ray 1936).

Teit (1930) described the yearly economic cycle of the Spokan as involving salmon fishing in the early summer and again in late summer/early fall with midsummer root digging. About eight to nine months of the year were spent moving between seasonal food gathering locations. Winter villages were occupied from December to March (Teit 1930), when subsistence depended upon stored fish, roots and winter hunting. Fishing technology included large nets, weirs, traps and spears (Teit 1930). In July of 1825, John Work observed Indians catching 700 to 800 fish per day at the Little Falls fishery site (Work 1830).

3.3.6.6 The Coeur D'Alene Indians

The Coeur d'Alene population occupied the Spokane River Valley from Spokane Falls to the headwaters, as well as portions of the North Fork of the Clearwater. Prior to adopting the horse as a form of transportation, the Coeur D'Alene consisted of four divisions that wintered at 16 permanent locations along the Spokane River Valley (Teit 1930). After acquiring horses, they began annual buffalo hunts to the Flathead country. The annual hunts grew in size until virtually the whole group participated (Teit 1930). According to Teit (1930), the annual bison hunting expedition departed in August after preserving roots, berries and salmon; the hunters did not return until April.

Salmon apparently did not penetrate the Spokane Falls on the Spokane River. Teit stated that the Coeur d'Alene "had no salmon in their own country, but salmon came close to the borders of their territory in the Spokane River" (Teit 1930). Salmon were, nonetheless, obtained by buying dried salmon from the Spokan or Palus Indians or by fishing at Spokane Falls and below. The latter was apparently practiced by large numbers of the Coeur D'Alene (Teit 1930). At least prior to the introduction of the horse, salmon were also taken from the upper tributaries of the North Fork of the Clearwater (Teit 1930).

Teit (1930) suggested that:

> Fishing and canoe travel were gradually forsaken for buffalo hunting and travel by horse. Since the forested country was not well adapted for horses, most of the tribe moved to the more open, grassy districts. This drew them away from the lakes and in great measure from fishing, canoes,...

The fishing alluded to here was probably for resident species. In general, Teit emphasized the profound change from many, relatively independent, sedentary bands to a large, unified tribe that moved constantly throughout the year. Teit's analysis, however, has been questioned for its inconsistency with historical evidence and for overstating the importance of bison hunting in Coeur D'Alene subsistence in the early 19th century (Anastasio 1972). These two viewpoints might be reconciled by suggesting that Teit may have been referring to the last half of the 18th century whereas Anastasio appeared to be referring to the first half of the 19th century. The bison, which had been plentiful west of the continental divide in Flathead country, apparently were hunted out by the early 1800s.

3.3.6.7 <u>The Kalispel Indians</u>

The Kalispel occupied the Pend d'Oreille and Clark Fork rivers from near the mouth of the Pend d'Oreille to Plains, Montana on the Clark Fork. The

Kalispel were sometimes referred to as the "Camas people" (Teit 1930), which may suggest the importance of this resource in their diet. Salmon were not available in the Pend d'Oreille River because of impassable falls, possibly Metaline Falls, in the lower river. Fulton (1968) suggested the blockage to fish migration was 32 kilometers upriver from the mouth. Salmon were harvested, however, in a small portion of Kalispel territory and beyond:

> In the salmon season, some Kalispel went down the river to near the canyon [probably Box Canyon], then across country to the head of the Salmon River in British Columbia, which was the northeast corner of their tribal territory, and there fished salmon. The salmon at this place were generally spent and poor, and in some years there were not many. A few Kalispel joined the friendly Lake and Colville at their great fishery about Kettle Falls; but most of the tribe procured dried salmon in trade from the Colville and Spokan, probably chiefly from the former. (Teit 1930)

3.3.6.8 The Pend d'Oreille Indians

According to Teit (1930), Pend d'Oreille territory comprised:

> ...all the Flathead Lake and Flathead River country, the Little Bitterroot, the Pend d'Oreille River west to about Plains, the Fork and Missoula rivers to about Missoula. Northward they extended to about the British Columbia line.

The usual wintering area was in the vicinity of Flathead Lake (Teit 1930). Bison were primary in the subsistence of the Pend d'Oreille after the arrival of horses, although some bison may have been used prior to that time. This dependence upon bison, and the accompanying conflict with the Blackfoot, led to the amalgamation of several smaller bands into one large band that wintered together. Natural barriers prevented anadromous salmonids from reaching Pend d'Oreille territory. According to Teit (1930), the Pend d'Oreille were "seldom able to obtain much [dried salmon] in trade."

3.3.6.9 The Flathead Indians

The Flathead proper are one of several groups including the Pend d'Oreille, Kalispel, and Spokan, which Teit (1930) called the "Flathead Group." Salmon runs did not reach Flathead country because of barrier falls in Kalispel territory (tentatively identified above as Metaline Falls). Nonetheless, the Flathead procured salmon outside their own country:

> By the time it reached the headwaters of the Idaho streams the salmon run was very weak indeed, but it was strong enough to cause an annual Flathead migration through the Lolo Pass into the boundaries of that modern state. The Indians say that they undertook this trip just as the streams swollen by the spring thaws began to fall. They say that they could expect salmon at that season and that they were succulent and fat.
>
> Arriving at the Idaho salmon country, each small band separated and chose its own stream across which to throw a weir.... If each band would fish its own stream there would be plenty of fish for all. (Turney-High 1937)

Because the construction of a weir was a communal enterprise, the catch was shared among the families present:

> The catch, once taken ashore, was gathered into a large pile under the chief's supervision. Bearers would then proceed from lodge-to-lodge around the circle while the chief counted aloud the number of each lodge. As the chief counted, a fish was laid before each lodge. It was considered a good day's work if the bearers made the rounds of a fair-sized camp as many as four times. (Turney-High 1937)

Any fish not consumed immediately were dried and pounded for winter consumption (Turney-High 1937). In addition to salmon that the Flathead procured themselves, Teit (1930) reported that the Flathead obtained dried salmon from the Lemhi Shoshone.

3.3.7 The Snake River Basin

The Snake River Basin consists of the entire Snake drainage, including all its tributaries above the Snake-Columbia confluence. Beginning at the mouth of the Snake, tribal groups were the Walla Walla (discussed in the Lower Columbia section), the Palus, the Nez Perce, Paiute, the Shoshoni and Bannock. There are minimal ethnographic data on the Palus, who occupied the Palouse River Valley and the vicinity of its confluence with the Snake. Palus salmon fishing would have been focused on the Snake because the Palouse drainage was blocked to fish migration by a high barrier falls. Data on Paiute use of salmon are also scarce. Better information is available on the other groups in the Snake Basin -- the Nez Perce, the Shoshoni, and the Bannock.

3.3.7.1 The Nez Perce Indians

The Nez Perce occupied the Snake River Valley from the mouth of the Tucannon River to the mouth of the Payette as well as most of the tributary valleys that enter along this reach. Included within this section is the entire Clearwater drainage, the lower Salmon River drainage, the Imnaha, and the lower Grande Ronde. Nez Perce winter villages extended along the rivers -- up the Salmon at least to Slate Creek and southward up the Snake to the Imnaha (Spinden 1909). Spinden (1909) listed 41 divisions or bands of Nez Perce totaling an estimated 6,000 people. Preferred locations for villages were near riffles, where salmon could be intercepted (Spinden 1909).

Spinden (1909) said of Nez Perce in general:

> In common with other tribes of the arid Basin areas, the Nez Perces depended for food largely upon vegetal products. They were not, however, as restricted in this respect as the tribes to the south, since salmon was plentiful during certain periods of the year and game was fairly abundant.

Camas and kouse were the primary plant food staples with a variety of other vegetal resources of secondary importance (Spinden 1909).

Fish, along with game, were said to have constituted "a considerable part of the food supply of the Nez Perces ..." (Spinden 1909). Four species of anadromous salmonids were listed by Spinden as native to the Nez Perce country (1909):

> 1) Red fish, or blue-backed salmon (Oncorhynchus nerka Walb.). This fish, varying from three to eight pounds in weight, was the favorite fish for drying. It was caught about the first of July on Clearwater River, but was taken much earlier at Wallowa Lake and at the head waters of Salmon River. Only the last of the run spawned on the lower stretches of the rivers.
>
> 2) Quinnat, Chinook, or Tyee salmon (O. tschawytscha Walb.). This salmon, averaging more than twenty pounds in weight, was caught somewhat later than the blue-backed salmon.
>
> 3) Steel-head salmon, "salmon trout" (Salmo gairdneri Richardson). This salmon was caught during fall and winter; it weighs usually about six pounds.

4) Cut-throat trout (S. mykiss Gibbsii Suckley).

Although Spinden listed a variety of other resident and non-salmonid species used by the Nez Perce, he stated that salmon were "by far the largest item." Salmon were both dried and smoked, but pemmican was not produced (Spinden 1909).

Fishing involved spears, nets, traps and hooks (Spinden 1909). With the trident or leister spear:

> ...large numbers of salmon were caught from platforms built out over the water or from jutting ledges of rock. The platforms were usually just above brush dams that almost closed the channel at the head of a riffle and which left only a small passage for the fish. Sometimes the fish were speared on riffles without the aid of the platform and the brush dam.

Salmon as well as eels were fished with several kinds of nets. Dip nets were used from platforms placed over natural or artificially created contractions in the channel. Weirs constructed of willow brush and stones were used in conjunction with platform fishing techniques. Seines that were 50 feet long and 15 feet deep were also used (Spinden 1909). According to Walker (1967), traps were built on smaller rivers, weirs on somewhat larger ones (e.g., the Middle and North forks of the Clearwater), and fish walls on channels too wide to span with weirs.

Walker (1967) presented evidence for the tremendous mobility of the Nez Perce in historic times. He has emphasized that Nez Perce fishing activities carried them to the major fisheries throughout the Columbia Basin -- Celilo Falls, Spokane Falls, Willamette Falls and others. Walker (1967), following Griswold (1953), has argued that a major factor contributing to salmon exploitation as far downstream as possible was the increased deterioration in the quality of salmon flesh with distance traveled inland. The extent of mobility suggested by Walker clearly depended upon horses.

Quantitative evidence for the productivity of the Nez Perce fisheries has been reviewed by Walker (1967) and is worthy of examination here. The missionary Henry Spalding, who settled among the Nez Perce in 1836, reported Nez Perce catches on a single day of 202 salmon with weights ranging between

10 and 25 pounds (Drury 1936 cited in Walker 1967). Spalding suggested that such catches may have been made simultaneously at 50 other locations within Nez Perce country. On July 25, 1839, and on July 27, 1839, Spalding reported Nez Perces in the Wallowa Valley making catches of 300 salmon and 600-700 respectively (Walker 1967). Numerous other examples were given of several hundred fish being taken in a day. Based on these observations, Walker (1967) suggested that:

> ...it is safe to conclude that the daily Nez Perce catch ranged some 300 to 700 salmon weighing from 10 to 40 pounds. My own research (Walker 1965-67), elaborated by Schwede (1966), indicates that Spalding's estimate of fifty fishing stations for Nez Perce territory also is a minimal figure. Taking the minimal 300 fish per day times the fifty fishing sites, one obtains a figure of 15,000 fish caught per day during the height of the season. Informants estimate that between June and October, there would be from 10 to 20 peak days when the catch would range from 300 to 700 salmon. Again taking their average weight as the minimal 10 lbs., the annual Nez Perce catch of salmon would be 1,500,000 lbs., or 300 lbs. per capita, precisely the figure given by Hewes for the Nez Perces....

3.3.7.2 The Shoshoni and Bannock Indians

The Shoshoni and Bannock groups of southern Idaho had highly varied subsistence systems. Some, such as the "Agaidika" or "salmon-eaters" of the Lemhi and Salmon rivers and the Fort Hall area, gained their primary subsistence from salmon fishing (Hultkrantz 1957). Others lived primarily on plants. Still others were equestrian bison hunters, little different in their basic economy from Plains tribes east of the continental divide. Through trade, dried salmon was a component of the diet of many Shoshoni and Bannock groups, whether or not runs actually reached group territories. In general, the groups most dependent upon fishing were those on the Snake below Shoshone Falls. The falls provided a rough boundary between the Eastern Shoshoni of southeastern Idaho, who were equestrians, and the Western Shoshoni of southwestern Idaho, who were largely unmounted. Mounted groups above the falls hunted bison and, in some cases, traveled to downstream fishing sites for fish.

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Bands located in the vicinity of the Boise, Weiser, and Payette rivers were near highly productive fisheries (Murphy and Murphy 1960). In 1812, a member of the Astoria party described the Boise River as...

> ...the most renowned Fishing place in the Country. It is consequently the resort of the majority of Snakes, where immense numbers of Salmon are taken. (Stuart 1935)

The productivity of this area was apparently greater than the salmon streams to the west in Oregon; northern Paiutes from that area crossed the Snake River to fish in the Boise and Weiser (Murphy and Murphy 1960). The first runs of salmon were said to have begun in March or April (Murphy and Murphy 1960). In all probability, this was too early for spring chinook runs and these were probably spring steelhead (Steward 1938). A second run arrived soon after and lasted through the spring (Murphy and Murphy 1960). These runs were exploited with traps. With the onset of summer, root harvesting attracted groups to the Camas Prairie where roots were dried throughout the summer. Root collecting activities continued up to late summer when these groups moved back to the rivers to hunt and dry fish for winter consumption (Murphy and Murphy 1960). Winter subsistence came from caches of dried roots, salmon and meat.

The Boise, Weiser, and Payette river region was also used by groups that did not winter in the area (Murphy and Murphy 1960). Mounted groups apparently came here to fish along with the permanent residents of the area, who had only a few horses. Some of these groups, such as the Fort Hall Bannock, apparently wintered here some years (Steward 1938).

A 210-foot vertical drop at Shoshone Falls imposed the upriver limit to the distribution of anadromous salmonids in the Upper Snake River. The area below, however, between Glenn's Ferry and Shoshone Falls, was described as being more important to the Shoshoni and Bannock who wintered above the Shoshone Falls than to the small population that wintered in the immediate vicinity (Murphy and Murphy 1960). The mounted groups that seasonally visited this area also took advantage of rich camas digging grounds at the Camas Prairie near Fairfield, Idaho (Murphy and Murphy 1960). The year-around residents of Camas Prairie were described as having few horses and, therefore, did not participate in the bison hunts.

Murphy and Murphy (1960) stated that the Shoshoni below Shoshone Falls "relied heavily on the salmon runs for food and fished during spring, summer, and fall" (1960). Steward (1938) reported that for the residents of this region "fishing was their primary subsistence." Their salmon caches were centrally located to yearly food-collecting sites. Fish weirs, nets, basket traps, hooks, and spears were mentioned as procurement techniques (Steward 1938; Murphy and Murphy 1960).

Three runs of salmonids were identified by Steward (1938) for this area:

> The first "salmon," probably the salmon trout, Salmo gairdneri, came about March or April....
>
> A second run of salmon came in May or June ... This is probably Oncorhynchus schawytscha (Walbaum), Chinook salmon.
>
> In the fall there was another run of salmon or, perhaps, salmon trout....

Three factors suggest that fish runs in the upper Snake Valley were not always dependable. First, winter Indian camps were small and dispersed, consisting of only two or three lodges (Murphy and Murphy 1960). This type of winter settlement was characteristic of people who depended largely upon dispersed plant or animal resources. Second, wintering was not always near salmon stores, and groups sometimes remained near their dried root caches instead (Steward 1938). Third, Steward (1938) alluded to occasional failures of the salmon runs on the Upper Snake.

The Bannock Creek and Northern Utah Shoshoni population, which became a predatory band prior to contact with Euroamericans, was a very mobile, mounted group (Murphy and Murphy 1960). They were described as unusual among Idaho Shoshoni in dependence upon the pine nut or pinyon (Pinus edulis) for winter subsistence. These Shoshoni are mentioned because some traveled to fish at Glenn's Ferry on the Snake "where they remained throughout the salmon run" (Murphy and Murphy 1960).

The Fort Hall Shoshoni and Bannock people adopted the horse relatively early and were primarily bison hunters (Murphy and Murphy 1960). Accordingly, they lived in larger groups than was characteristic of other Shoshoni. Portions of this group would travel to Glenn's Ferry to fish for salmon. Fish apparently were consumed fresh during the fishing season, but not preserved for use later. The Fort Hall people fished with harpoons rather than with weirs (Murphy and Murphy 1960), which probably reflected the lack of demand for a surplus to preserve. The groups wintered upon dried buffalo, elk and deer from the fall hunts (Murphy and Murphy 1960).

The Lemhi Valley and Stanley Basin region in the mountainous headwaters of the Salmon River were occupied by bands of Northern Shoshoni, referred to as the Lemhi and Tukaduka (Steward 1938). The populations occupying the mountains of the Upper Salmon river were horseless while those of the Lemhi Valley owned large numbers of horses (Steward 1938). Lewis and Clark, who provided an excellent account of the Lemhi, estimated that the Lemhi had 400 horses when Lewis and Clark visited these people in 1804. Steward (1938) estimated the combined populations of the Lemhi and Tukaduka as about 1,200 individuals. Ferris (1940), a fur trapper who traveled through the headwaters of the Salmon River in June 1831, described the Northern Shoshoni subsistence as follows:

> Here we found a party of "Root Diggers" or Snake Indians without horses. They subsist upon the flesh of elk, deer, and bighorns, and upon salmon which ascend to the fountain sources of this river, and are here taken in great numbers. These they first split and dry, and then pulverize for winter's provision. They often, when unable to procure fish or game, collect large quantities of roots for food, whence their name. We found them extremely anxious to exchange salmon for buffalo meat, of which they are very fond, and which they never procure in this country, unless by purchase of their friends who occasionally come from the plains to trade with them. (Ferris 1940 cited in Murphy and Murphy 1960)

Citing historical accounts, Steward (1938) noted that "foods were not plentiful" for these Shoshoni groups. Steward (1938) listed the following salmonids that were taken in the Upper Salmon and its tributaries:

> 1) "a variety up to 18 inches long, which could be taken all winter; in March they went into small streams to spawn." Steward tentatively identified this species as steelhead trout.
>
> 2) A "redfish" taken in August, which Steward did not identify further, but may be sockeye;
>
> 3) Chinook salmon taken in August.

Weirs were used on the Lemhi River, but apparently not on the Upper Salmon. Other techniques included hooks, harpoons, baskets and dams (Steward 1938).

To judge from Lewis and Clark's observations, salmon did not seem plentiful far up the watershed in August 1805:

> ...one man killed a Small Sammon, and the Indians gave me another which afforded us a Sleight brackfast. Those Pore people are here depending on what fish they can catch, without anything else to depend on... (Thwaites 1905)
>
> ...one Indian out all day & killed only one Sammon with his gig. (Thwaites 1905)

According to Murphy and Murphy (1960), the Lemhi remained on the rivers fishing from May through September. Evidence also shows that some families traveled to the Camas Prairie in summer while others hunted bison (Steward 1938). Murphy and Murphy (1960) also mentioned use of a spring salmon run in April which is most plausibly interpreted as the steelhead runs. No clear or explicit report of fish storage for winter consumption exists. There is, as with Shoshoni groups between Weiser and Shoshone Falls, indication that the fishery was split into a spring/early summer season and a late summer/fall season (Murphy and Murphy 1960).

Steward (1938) summarized the nature of fishing on the Upper Snake as follows:

> The Snake River is [within the Great Basin] unique in having salmon, but their quantity and quality were somewhat less than nearer the coast. When running, the fish were sufficiently abundant to supply all who could take them. The main limitation upon them was their occasional failure to run and the restricted number of convenient fishing places. Large numbers of people gathered at fishing places, some cooperating in constructing dams and weirs, others fishing

> alone with spears, hooks, and other devices. The catch was dried for winter. Though salmon afforded considerable food, all accounts indicate that they were rarely sufficient to keep families in plenty during the remainder of the year. Consequently, subsistence was supplemented by vegetable foods and hunting.... Both game and vegetable foods required unusually long journeys, either to the camas country to the north or to the highlands to the south. Families returned to their salmon caches along the Snake River to winter if the catch had been good; otherwise they remained where the vegetable harvest had been abundant.

3.3.7.3 The Northern Paiute Indians

The area of the Great Basin occupied by the Northern Paiute covered central and eastern Oregon, northeastern California, and most of western Nevada. Rivers that produced chinook salmon and steelhead included the Malheur, the Owyhee, and the headwaters of the Deschutes and John Day (Fulton 1968; 1970).

According to Whiting (1950), the yearly economic cycle of the Wadadika, who were centered around Malheur and Harney lakes in eastern Oregon, began with root-digging in early May. While the women were still preparing roots for storage, the men moved to the Drewsey, a tributary of the Malheur River, where they repaired and installed their fish traps in preparation for the spring salmon run. When the runs began, the women joined the men on the river to assist in drying salmon. From the end of the spring salmon run until movement into winter camps in November, individual families dispersed to hunt (deer, sagehens, ground hogs, antelope, rabbits), and collect seeds, roots, berries and crickets. Winter subsistence depended upon a variety of stored seeds and roots, crickets, chokecherries, dried meat and fish (Whiting 1950). Although only available for brief periods, salmon, crickets, and wada seeds were the only resources that were plentiful enough to permit more than a few families to congregate.

The "Salmon eaters," or Paiute groups that occupied the lower Malheur River, undoubtedly had access to more salmon and steelhead, but details of their subsistence are lacking. Similarly, the "Tagu eaters," or Paiutes whose territory centered about the Owyhee River, must have depended to some extent upon salmon.

3.3.8 Summary

It is clear from the ethnographic, ethnohistoric and archaeological records that the aboriginal peoples of the Columbia River Basin were dependent upon the salmon and steelhead. The degree of this dependence varied in response to resource availability and therefore largely on the geographic location of any particular tribal group. Understanding this relationship is important to taking the next step in this exercise -- estimating consumption and aboriginal catch.

3.4 THE MAGNITUDE OF ABORIGINAL CATCH IN THE COLUMBIA BASIN BEFORE 1850

Using aboriginal population estimates for the Columbia drainage and estimates of the amount of fish consumed per person per year, figures can be generated for the total annual Indian catch of salmon and steelhead in the early 19th century.

It is important to note that aboriginal catch does not represent pre-1850 run sizes. Estimated catch does, however, provide a number on which to base discussion. Two previous catch estimates are considered here. After discussing these two estimates, a third is generated.

3.4.1 The Craig and Hacker Estimate

The earliest effort to estimate the amount of salmon taken by Columbia Basin Indians in the early 19th century is by Craig and Hacker (1940). They postulated that the Indians ate an average of one pound of salmon per day or 365 pounds per capita annually. Using Carey's (1922) estimate of 50,000 Columbia River Indians in the early 1800s, Craig and Hacker estimated 18 million pounds of salmon were harvested a year.

3.4.2 The Hewes Estimate

Using ethnographic data from central California to Alaska and the Yukon, Hewes estimated a total yearly salmon catch of over 127 million pounds for the entire area. To generate this estimate, Hewes (1947; 1973) relied on four kinds of information:

1. Average human daily caloric requirements per capita (estimated at 2,000 calories per day).

2. Caloric content per pound of salmon (estimated at about 900 calories per pound).

3. Estimates derived from ethnographic accounts of the importance of salmon to various native groups.

4. Aboriginal population estimates by Mooney (1928), as revised by Kroeber (1939), for 1780, the period immediately prior to major disease impacts.

In contrast to Craig and Hacker's estimators, Hewes' approach attempts to account for the variability in salmon dependence from group to group and region to region. From Hewes' data, an estimate of the total salmonid catch for the Columbia drainage can be tabulated. In Table 10, compiled from Hewes (1973), the various native groups of the Columbia Basin are shown along with estimates of populations, pounds of salmon consumed per capita annually, and pounds consumed per group annually. From numbers in the table, the total annual aboriginal catch for the Columbia drainage in pre-contact times would be more than 22 million pounds of fish per year. This figure, based upon more thorough consideration of ethnographic data than that of Craig and Hacker, is higher than their 18 million estimate, but in the same order of magnitude. The principal difference between these two figures is that Hewes relied on more accurate population estimates by Kroeber (1939) rather than the earlier, lower estimates used by Craig and Hacker. (Using the Craig and Hacker procedure, but substituting Kroeber's population estimate of 61,500 for the Columbia Basin, the estimate of salmonids consumed in the Columbia drainage rises to 22,274,500.)

Craig and Hacker and Hewes assumed that a pound of salmon per day per person, or 365 pounds per year, was a reasonable average for the entire Columbia drainage. Craig and Hacker's estimate was based on only limited use of the ethnographic and ethnohistoric data. Their estimate also may have been influenced by information regarding per capita consumption of Indians fishing at Celilo Falls in the 1930s. Hewes' per capita annual consumption estimates for individual groups were based on the assumption that a pound of

Table 10 - Estimates of population and annual salmonid consumption for Columbia Basin tribal groups prior to arrival of Euroamericans (circa 1780).[1]

Native Groups	Population	X	Estimated Annual Consumption: Per Capita (lbs.)	=	Estimated Annual Consumption: Total by Groups (lbs.)
Chinook	22,000		400		8,800,000
Tlatskanai	1,600		365		584,000
Kalapuya	3,000		100		300,000
Cowlitz[2]	1,200		365		438,000
Klickitat, Yakima, Wanapum, Palus	11,200		400		4,480,000
Tenino, Umatilla, Walla Walla	2,900		500		1,450,000
Cayuse	500		365		182,500
Wenatchi, Sinkiuse, Peskwaus, Methow, Nespelem, Sanpoil, Colville (part)	3,500		500		1,750,000
Wenatchee-Spokan group (part)	2,400		500		1,200,000
Kalispel, Coeur d'Alene Pend d'Oreille, Flathead	2,800		100		280,000
Okanogon, Lakes	2,200		500		1,100,000
Kutenai	1,200		300		360,000
Nez Perce	4,000		300		1,200,000
Bannock, North Paiute, North Shoshoni	3,000		50		150,000
TOTALS	61,500				22,274,500

[1] Note that the tribal groups listed do not necessarily represent the same groups of present day tribes with the same or similar names.

[2] Kroeber combines his population estimates for the Cowlitz with that for the Chehalis and Willapa -- areas outside the Columbia drainage system. However, Taylor (1963) provided a revised estimate of 900-1,200 for the Cowlitz alone, so the figure of 1,200 was retained.

salmon provided about half the minimum daily caloric requirements of an average person (Hewes 1973). Hewes weighted the average 365 pounds per year consumption figure for each tribal group by using his analysis of the ethnographic data on the relative importance of salmon from group to group in the basin.

The Hewes estimate appears to be low for a number of reasons. The first, and possibly most important, is that it assumes a caloric content for salmon as they enter freshwater. Since salmonids lose an average of 75 percent of their caloric content during freshwater migration (Idler and Clemens 1959), some adjustment should have been made for distance traveled upstream. As will be shown below, the total annual per capita estimate for fish consumed rises significantly when a migration calorie-loss factor is included.

A second reason that the Hewes estimate is likely to be low is that it assumes that salmon were eaten in their entirety -- an unrealistic assumption. According to Hunn (1981), about 80 percent of the weight of a salmon is edible.

A third reason for suggesting that Hewes' consumption estimates are too low, is that he only considers human dietary demands. At least three other uses of salmon have been reported -- food for dogs (Thwaites 1904), fuel where wood was scarce (Thwaites 1904), and for trade.

3.4.3 A New Estimate of Aboriginal Fish Consumption for the Columbia Basin

Recognizing that some important factors were not considered in the earlier estimates of the total annual aboriginal salmonid consumption in the Columbia Basin in the early 1800s, it is appropriate to attempt a new estimate. The three adjustments to Hewes' calculations consist of 1) revision of his per capita consumption estimates for certain groups, 2) inclusion of a migration calorie-loss factor, and 3) inclusion of an inedible-waste factor.

The ethnographic literature covered in this study, some of which was not available to Hewes at the time of his study, suggests that Hewes' per capita estimates for four groups of aboriginal inhabitants are either too high or too low. Assuming, as Hewes did, that 365 pounds of salmon were roughly equivalent to half the minimum annual caloric requirement for an average individual, Hewes' estimates seem too low for Chinook Indians and too high for the Cowlitz and Kutenai. The estimate for the combined Okanagon and Lakes Indians also appears high.

There is nothing in the ethnographic evidence to suggest that the Chinook Indians depended any less on salmonids than the Tenino, Umatilla, Walla Walla or Wenatchi. Therefore, raising the 400 pounds per capita estimate for the Chinook to 500 pounds, as assigned to these other groups, is more consistent with the ethnographic data. Judging from the limited ethnographic evidence discussed earlier, the Cowlitz' per capita estimate seems rather high and has been adjusted from 365 pounds to 200 pounds per capita. The Hewes estimate for the Kutenai has been reduced from 300 pounds to 150 pounds per capita, and the combined estimate for the Okanogon and Lakes from 500 pounds to 400 pounds per capita.

An adjustment for caloric loss during migration was the second important modification to Hewes' procedure. Following Hunn (1981), the calorie loss factor is computed as a ratio of the entire length of the Columbia (1,936 km) to the distance in river-kilometers from the mouth of the Columbia to the approximate middle of each group's territory. If a group was located entirely on a tributary, then the ratio was calculated as the distance from the mouth of the Columbia to the middle of the group's territory over the distance to the upriver limit of salmon in that tributary. This ratio is then multiplied by 0.75, the average calorie loss during salmon migration, and the product subtracted from one. All distances were taken from Fulton (1968, 1970).

The third component of the revised estimate involves dividing the per capita consumption estimate by a waste factor of 0.8 to get the weight of fish used. The loss factor is derived from Hunn's suggestion that 80 percent of the total weight of a salmon is edible.

Table 11 presents the data used in these calculations. Calculating per capita catch for each group involves multiplying Hewes' per capita

Table 11 - Annual salmonid catch estimates by tribal groups using migration calorie loss and waste factors.[1]

Native Groups	Hewes' Per Capita (lbs.)	Migration Calorie Loss Factor	Per Capita Consumption Adjusted for Calorie Loss (lbs.)	Waste Factor	Per Capita Catch (lbs.)	Estimated Total Catch (lbs.)
Chinook	500	.94	532	0.8	665	14,630,000
Tlatskanai	365	.97	376	0.8	470	752,000
Kalapuya	100	.49	204	0.8	255	765,000
Cowlitz	250	.50	500	0.8	625	750,000
Klickitat, Yakima, Wanapum, Palus	400	.58	690	0.8	863	9,665,600
Tenino, Umatilla, Walla Walla	500	.84	595	0.8	744	2,157,600
Cayuse	365	.81	451	0.8	564	282,000
Wenatchi, Sinkiuse, Peskwaus, Methow, Nespelem, Sanpoil, Colville (part)	500	.64	781	0.8	976	3,416,000
Wenatchi-Spokan group (part)	500	.66	758	0.8	948	2,275,200
Kalispel, Coeur d'Alene, Pend d'Orielle, Flathead	100	.57	175	0.8	219	613,200
Okanogon, Lakes	400	.40	1,000	0.8	1,250	2,750,000
Kutenai	150	.39	385	0.8	481	577,200
Nez Perce	300	.58	517	0.8	646	2,584,000
Bannock, N. Paiute N. Shoshoni	50	.35	143	0.8	179	537,000
			TOTAL			41,754,800[2]

[1]Note that the tribal groups listed do not necessarily represent the same groupings of present day tribes with the same or similar names.

[2]Approximately 4.5 to 5.6 million fish (see Table 31).

consumption estimate (Column 1) by the migration calorie loss factor (Column 2) to get an adjusted per capita consumption estimate (Column 3). This adjusted per capita consumption estimate is then divided by 0.8, the waste factor (Column 4), to arrive at the per capita annual catch estimate (Column 5). To obtain annual catch estimates for tribal groups (Column 6), the per capita annual catch estimate is multiplied by the population estimates in Table 10. Calculated in this way, the annual salmonid catch by Columbia River Basin Indians in the early 19th century is estimated to be nearly 42 million pounds.

Although this figure is nearly twice as large as previous estimates, there are reasons to suspect that it may be low. The aboriginal population estimates are central to these calculations, but these estimates are only rough approximations. Almost half a century has passed since the population estimates were examined systematically for the region.

Since Mooney's original study of aboriginal populations, the only comprehensive reanalysis of historical data on this subject is a recent study by Robert Boyd (1985). He provides a reconstruction of the epidemic history of these two areas of the Columbia Basin and documents significant differences in their patterns of disease history and population decline.

Using methods of historical demography and crosschecking the reliability of various estimates, Boyd provides revisions to the Lewis and Clark estimates upon which Mooney largely depended. Although Boyd revises the Lewis and Clark estimates downward for some groups in the basin, he raises the estimates for a number of groups. Boyd's revisions result in a population estimate of about 60,000 for the Columbia Basin in 1805. The cumulative result of his revisions is a figure that is close to Mooney's figure for the pre-epidemic population of the basin. In other words, Boyd's analysis suggests that population levels were as high in 1805 after two major smallpox epidemics had occurred as Mooney had estimated for the period immediately preceding the epidemics. Based upon an estimated combined mortality rate of 45 percent for the 1775 and 1801 epidemics, Boyd projects populations for the Columbia Plateau tribes for the interval immediately before 1775. His pre-epidemic estimates do not include lower Columbia or upper Snake River groups, but application of the same mortality rates to the other groups of the basin suggests that roughly 100,000 people may have occupied the basin in the early 1770s.

Use of these higher population estimates in calculations similar to those presented above would result in a higher estimate for the total aboriginal salmonid catch in the Columbia Basin. That will not be done here because the approach to estimating consumption levels used above requires both population estimates and average annual per capita consumption rates for individual groups. In developing his per capita estimates, Hewes relied on an extensive body of ethnographic and ethnohistoric literature that was quite relevant to the early part of the 19th century. The relevance of that same data base to the period prior to 1775, however, is not so clear. There are no ethnographic or ethnohistoric accounts available for that earlier time period and, as was noted earlier in the chapter, this was an interval of dynamic change. With the mobility options provided by the horse, demographic changes would almost certainly have been accompanied by changes in the nature and extent of salmonid exploitation.

The catch estimates presented here did not consider uses of salmon other than as food for humans. At least three other uses are documented in the ethnohistoric accounts: for dog food, for fuel, and for trading. Dogs can be traced many centuries back into the prehistory of this region and there can be little doubt that fish were used for feeding dogs. The Lewis and Clark expedition, which periodically subsisted on dogs obtained from Indians, complained of the dismal quality of the dogs before the arrival of the salmon in the spring (Thwaites 1905).

As indicated in earlier sections of this chapter, there was extensive trade in salmon in numerous different areas of the Columbia Basin. Kalapuyan groups, which lacked fall run salmon in their own territory, traded for salmon at the Willamette Falls. Chinookans that fished at the falls of the Willamette traded spring run salmon to the Cowlitz. The Wishram and Wasco seem to have been the focal point in the most extensive trade network in the plateau -- one that reached to the mouth of the Columbia and out onto the plains east of the Rockies. They traded dried fish for bison hides and other commodities that originated on the plains (Griswold 1953). On a reduced scale, Kettle Falls, Okanogan Falls, and Spokane Falls appear to have been centers for salmon trade in their respective areas.

Horses greatly facilitated trade of bulky subsistence items, such as fish, and groups such as the Nez Perce, which owned large numbers of horses, played key roles in conveying dried salmon from fish-rich areas to fish-poor areas. Although it is difficult to quantify the amount of salmon traded annually, two points seem clear. The first is that much of the salmon, probably the vast majority that was traded, was traded to groups within the basin. (The fish traded within the basin already have been quantified in the tribal consumption estimates discussed in a previous section.) The second point is that much of the fish that was actually taken beyond the boundaries of the Columbia watershed was taken eastward by groups positioned at or near the headwaters of the basin (e.g., Shoshoni, Nez Perce). In view of the periodic shortfalls in salmon harvests that were documented during the first half of the 19th century, it is likely that extra-basin trade primarily involved surpluses during years when runs were strong enough to exceed the needs of local populations within the basin.

The last step in this process is to convert the aboriginal catch from pounds to numbers of fish. The aboriginal catch is difficult to convert to numbers of fish because the proportion of the catch represented by any particular species cannot be determined with any precision. One way to solve this problem is to assume that the species composition in the aboriginal catch was proportional to the species composition in the lower river commercial catch from 1880 to 1920. Using this method, a range of about 4.5 to 5.6 million fish can be estimated for aboriginal catch (Table 12). Therefore, it can be estimated using biological, ethnographic, and historical data that a population of about 50,000 to 62,000 Columbia Basin aboriginal peoples caught about five to six million fish annually in the early 1800s.

Table 12 - Aboriginal catch in numbers of fish.

Species	Lower River Catch Range[1]	% of Total Lower River Catch	Aboriginal Catch in Pounds per Species[2]	Average Pounds Per Fish[3]	Aboriginal Catch Range Expressed as Numbers of Fish
Spring chinook	400,000 - 1,150,000	6 - 14	2,505,000 - 5,846,000	18.5	135,000 - 316,000
Summer chinook	1,700,000 - 2,300,000	26 - 28	10,856,000 - 11,691,000	18.5	587,000 - 632,000
Fall chinook	1,100,000 - 1,150,000	17 - 14	7,098,000 - 5,846,000	18.5	384,000 - 316,000
Sockeye	1,905,000 - 1,300,000	30 - 16	12,526,000 - 6,681,000	3.5	3,579,000 - 1,909,000
Coho	605,000 - 890,000	9 - 11	3,758,000 - 4,593,000	8.9	422,000 - 516,000
Chum	359,000 - 697,000	6 - 9	2,505,000 - 3,758,000	12.2	205,000 - 308,000
Steelhead	382,000 - 674,000	6 - 8	2,505,000 - 3,340,000	7.3	343,000 - 458,000
Total	6,451,000 - 8,161,000				5,655,000 - 4,455,000

[1]Range is based on a five-year mean and a one-year peak catch in the lower Columbia River commercial fishery (see Chapter 2).

[2]Aboriginal catch (41,754,800) multiplied by percent of each species in the lower river catch.

[3]Beiningen 1976a.

Chapter 4

DECLINES IN FISH RUNS AND HABITAT

4.1 INTRODUCTION

As a basis for assessing the magnitude and causes of losses of salmon and steelhead, it is important to look at changes in fish runs and their habitat over time. Sizes of fish runs fluctuate through time in response to changes in climate, water supply and other natural phenomena. In addition, many of man's activities, as described in Chapter 5, influence these fluctuations.

This chapter reviews the changes in salmon and steelhead runs, and the habitat used by these species, from the beginning of development (about 1850) to the present. Descriptions of runs are based on adult fish counts and redd counts. Another set of data that is useful in assessing fish abundance is harvest records. Generally, prior to 1938, lower river commercial catches are the best indicators of fish run size because fish counts and redd counts are not usually available for this time period. Information on fishing is displayed in the fishing section of this compilation (see Section 5.2).

For purposes of discussion, the Columbia River Basin is separated into six major areas described in Table 13. Fish species discussed are chinook (spring, summer, and fall runs), coho, sockeye, and chum salmon and steelhead trout.

4.2 ADULT FISH AND REDD COUNTS

4.2.1 Overview

Adult fish counts have been made at various locations in the Columbia River Basin (e.g., dams, waterfalls, hatchery racks, spawning grounds). Adult fish counts give a rough estimate of escapement and can be used in combination with catch estimates to determine run size.

Redd (fish spawning nest) counts are done annually in many areas of the Columbia Basin. Redd counts are best used for assessing the relative abundance and trends of fish runs and not as absolute measures of population abundance because they are generally done only once each year for each area.

Table 13 - Columbia River Basin description.

Major Area	Major Tributary River Basins	
Columbia River Below Bonneville Dam	Sandy Washougal Lewis and Clark Youngs Cowlitz	Lewis Kalama Grays Willamette Columbia River mainstem
Columbia River Between Bonneville Dam and its confluence with the Snake	Walla Walla Umatilla John Day Deschutes Hood	Klickitat White Salmon Little White Salmon Wind Columbia River mainstem
Columbia River Between its confluence with the Snake River and Chief Joseph Dam	Methow Okanogan Wenatchee Chelan	Entiat Yakima Columbia River mainstem
Columbia River Above Chief Joseph Dam	Sanpoil Kettle Pend Oreille Spokane	Coeur d'Alene St. Joe Kootenay Columbia River mainstem
Snake River Below Hells Canyon Dam	Salmon Grande Ronde Clearwater	Tucannon Imnaha Snake River mainstem
Snake River Above Hells Canyon Dam	Powder Malheur Owyhee Boise Payette	Bruneau Burnt Weiser Snake River mainstem

The problem with using one-time "peak" redd count data for stock trend analysis is that the timing of spawning varies annually (Schwartzberg 1985). Ocean conditions, river flows and temperatures, passage obstructions, dam delays, irrigation patterns, and pollutant discharges are examples of factors that influence the timing of salmon and steelhead spawning (USFWS 1981).

Fish and redd counts are converted into run size in some instances. This conversion involves estimating the number of fish the count represents. Usually no conversion is necessary for dam counts where every fish is potentially counted. Redd and fish counts on the spawning grounds require an estimate of fish per redd or fish per fish counted. The last step in estimating run size is to add numbers of fish caught to the converted count.

Because adult fish counts at mainstem Columbia River dams are indicative of abundance of all fish runs originating above the count points, counts below the confluence of the Snake and the Columbia are presented separately from the six specific areas identified in Table 13. Therefore, tributary counts are the only counts included in the fish runs description for the two lower Columbia areas.

4.2.2 Mainstem Dam Fish Counts and Run Size Estimates Below the Confluence of the Snake and Columbia Rivers

Fish counts on the mainstem Columbia River are made at the four Corps of Engineers dams: Bonneville, The Dalles, John Day, and McNary. Figures A-15 through A-29 (Appendix A) show counts of salmon and steelhead at these dams since their construction (see also Appendix A, Tables A-3 through A-6). These figures generally indicate a decline in salmon and steelhead abundance, particularly at the dams upstream from Bonneville Dam.

Using dam counts, an estimate has been made for run sizes of spring, summer, and fall chinook and sockeye salmon, and steelhead (Table 14) produced above Bonneville Dam in the 1950s. The average inriver run (column 2) is a combination of Bonneville Dam counts and inriver harvest below Bonneville Dam. Column 3 applies estimated ocean harvest rates to the inriver run size to estimate ocean harvest (column 4). Adding average inriver run (column 2) to estimated ocean catch (column 4) yields the estimated average total run (column 5) of 2,257,200 fish.

Table 14 - Run sizes of Columbia Basin salmon and steelhead in the 1950s based on dam counts (CBFWC 1986, Junge 1980, Fish Commission of Oregon and Washington Department of Fisheries).

Species/Race	Inriver Average Run Size Above Bonneville Dam	Ratio of Ocean Catch to Inriver Run Size	Estimated Ocean Catch	Estimated Average Run Size Originating Above Bonneville Dam	Estimated Maximum Run Size Originating Above Bonneville Dam[4]	Estimated Minimum Run Size Originating Below Bonneville Dam[5]
Spring chinook[1]	230,200	0.1	23,000	253,200	300,000	64,946
Summer chinook[2]					200,000	
Snake River	121,500	0.1	12,100	133,600		
Mid-Columbia R.	59,900	2.9	173,700	233,600		
Fall chinook[2]	276,900	2.9[3]	803,000	1,079,900	1,200,000	35,080
Sockeye[1]	241,500	--	--	241,500	250,000	
Steelhead[1]	315,400	--	--	315,400	400,000	57,740
				2,257,200	2,350,000	

[1]1951-55 average.

[2]1955-59 average.

[3]Ratio based on average of data from 1961-64 fall chinook marking studies presented by Pulford (1970) and Wahle and Vreeland (1978).

[4]Junge 1980.

[5]Minimum runs sizes are from Fish Commission of Oregon and Washington Department of Fisheries (1972).

Another 1950s run size estimate for production above Bonneville Dam based on dam counts expanded for harvest was done by Junge (1980). Junge's estimates are shown in column 6 of Table 14. His estimate of a maximum total run of 2,350,000 is for the period in the early 1950s before McNary Dam was constructed.

Estimated minimum run sizes for spring and fall chinook, and steelhead are also displayed in column 7 of Table 14. These estimates do not include all escapement and do not include ocean catch and are therefore considered minimum. Estimates for coho are not available prior to 1960.

4.2.3 Columbia River Below Bonneville Dam

4.2.3.1 Spring Chinook

Annual counts of spring chinook have been taken at Willamette Falls since 1946 (Bennett 1985). The trend in count is generally upward (Appendix A, Figure A-49). The fishway at the falls, completed in 1971, made habitat more accessible to spring chinook.

Spring chinook escapement over Leaburg Dam on the McKenzie River, in the Willamette Basin, was 13,200 and 9,000 in 1958 and 1959, respectively. Counts have fluctuated between 1,078 and 3,870 fish since 1970 (Appendix A, Figure A-50). Cougar Dam, built in the 1960s, destroyed about one-third of the potential production area above Leaburg Dam (Willis et al. 1960).

Escapement of spring chinook over North Fork Dam on the Clackamas River, a major tributary to the Willamette, showed a dramatic increase in 1980 to 1983 from an annual average below 1,000 fish to an annual average of over 2,500 fish (Appendix A, Figure A-51). This has apparently been the result of returns from smolt releases at the Clackamas Hatchery (Bennett 1984). In general, increased hatchery production has increased returns of Willamette River drainage stocks (Beiningen 1976b).

Indications of pre-dam spring chinook run sizes in Washington lower Columbia tributaries include all time peak counts of 7,300 at Merwin Dam (1940) on the Lewis River, and 17,300 at Mayfield Dam (1965) on the Cowlitz River.

Estimated spring chinook run sizes for the Cowlitz, Kalama, and Lewis rivers since 1969 are shown in Appendix A, figures A-52 and A-53. Run sizes for these three basins have fluctuated with no apparent trend.

4.2.3.2 Summer Chinook

Summer chinook are not produced in this area of the basin.

4.2.3.3 Fall Chinook

Annual counts of fall chinook have been taken at Willamette Falls since 1955 (Appendix A, Figure A-54). Counts indicate an upward trend for Willamette River fall chinook.

Fall chinook fish and redd counts for the Sandy River (Trout and Gordon creeks) are shown in Appendix A, Figure A-55. There is no apparent trend over the years, but the 1981-83 counts dropped to 0 to 3 fish and 0 to 4 redds, possibly indicating the demise of this run.

Run sizes for naturally spawning fall chinook based on redd and peak fish count expansions for the North Lewis, East Lewis and Cowlitz rivers is shown in Appendix A, figures A-56, A-57, and A-58. Downward trends in abundance are indicated for the Cowlitz and East Lewis. No trends are apparent for the North Lewis.

4.2.3.4 Coho

Counts at Willamette Falls and North Fork Dam on the Clakamas River for coho salmon have fluctuated over the years (Appendix A, figures A-59 and A-60). Since 1977, counts at Willamette Falls have stabilized at under 2,000 from a high of 17,902 in 1970.

Spawning ground counts in lower Columbia River tributaries (Youngs River and Little, Willark, Carcus, Milton, Salmon, Sierkes, Raymond, Deep and Trickle creeks) indicate a declining trend in coho abundance (Appendix A, Figure A-61).

4.2.3.5 Sockeye

No counts are available for sockeye in this area of the basin.

4.2.3.6 Chum Salmon

Chum spawning ground counts in lower Columbia River tributaries have shown a relatively steady decline in numbers since the early 1960s counts of over 350 fish per mile to the record low of 14 fish per mile observed in 1981 (Appendix A, Figure A-62). Chum salmon counts are done for the Grays River and Hardy and Hamilton creeks (ODFW 1985b).

4.2.3.7 Steelhead

Counts of winter steelhead have been taken since 1950 at Willamette Falls (Appendix A, Figure A-63). These counts indicate a general upward trend in abundance. Counts at the Eagle Creek National Fish Hatchery rack and North Fork Dam on the Clackamas have fluctuated without an apparent trend (Appendix A, figures A-64 and A-65). Winter steelhead counts at Marmot Dam on the Sandy River have also fluctuated since 1966 without an apparent trend (Appendix A, Figure A-66).

Summer steelhead counts in the Willamette and Sandy basins have indicated an upward trend in abundance (Appendix A, Figures A-67).

4.2.4 Columbia River Between Bonneville Dam and Its Confluence with the Snake River

4.2.4.1 Spring Chinook

Minimum freshwater adult spring chinook run sizes have been estimated for the Klickitat, Little White Salmon, and Wind rivers since 1970 (Appendix A, figures A-68, A-69, and A-70). These estimates are computed by adding catch, hatchery returns, and expanded spawning ground counts of fish and redds (ODFW 1985b). These estimates fluctuate without any apparent trend.

Redd counts for the Warm Springs River, the major spring chinook natural production area left in the Deschutes Basin, are shown in Appendix A, Figure A-71). Average spring chinook redds per mile for the John Day River are shown in Appendix A, Figure A-72). The John Day spring chinook appear to be declining in abundance while the Deschutes data indicate no trend.

4.2.4.2 Summer Chinook

No summer chinook are produced in this area of the basin.

4.2.4.3 Fall Chinook

The Deschutes River fall chinook adult run size is shown in Appendix A, Figure A-73 for 1977 to 1983. Run size was estimated by adding escapement based on redd and fish counts to harvest (ODFW 1985b). The Deschutes fall chinook population appears to be stable according to this data.

4.2.4.4 Coho Salmon

The only counts of coho salmon found for this area of the Columbia Basin were for Powerdale Dam in the Hood Basin (Appendix A, Figure A-74). No trend is apparent from these counts.

4.2.4.5 Sockeye

Mainstem dam counts are the only counts available in this area of the basin (see 4.2.2).

4.2.4.6 Chum Salmon

No counts are available for chum in this area of the basin.

4.2.4.7 Steelhead

Counting of Umatilla summer steelhead has occurred at Three Mile Dam since 1966 (Appendix A, Figure A-75). A slight downward trend in abundance is apparent in this data.

Summer steelhead spawning ground data for the John Day Basin expressed in average redds per mile is shown in Appendix A, Figure A-76 for 1959 to 1984. A downward trend is apparent in this data also.

Summer steelhead counts at Sherars Falls in the Deschutes Basin occurred from 1977 to 1983 (Appendix A, Figure A-77). This data shows no trend in abundance.

Steelhead counts were taken at Powerdale Dam in the Hood Basin in 1955 and 1962 to 1970 (Appendix A, Figure A-78). These counts include both winter and summer steelhead and were taken from November through October (except 1955-February to July, 1962-April to October, 1964-November to April, 1969-no winter steelhead count). Note that the count extends over the end of the count year and into the beginning of the following year (ODFW 1985b).

Winter steelhead range extends east in the Columbia Basin to Fifteenmile Creek at The Dalles. Average redd counts per mile are shown in Appendix A, Figure A-79 for the basin. These counts have occurred intermittently since 1964 and indicate a drastic decline after the initial year count average of 17.4 per mile.

4.2.5 Columbia River Between Its Confluence with the Snake and Chief Joseph Dam

Fish counts are made at four dams on the mainstem Columbia River in this area: Priest Rapids, Rock Island, Rocky Reach, and Wells. Tables A-11 through A-14 (Appendix A) show counts of salmon and steelhead at these dams since their construction.

Fish counts over Rock Island Dam since 1933 provide the earliest indicators of the status of upriver populations of anadromous salmonids in this area of the Columbia River (Appendix A, Table A-12). There was a general increase in average numbers of salmon and steelhead counted at Rock Island Dam from the early 1940s until the late 1960s. Since then, a downward trend is apparent (Appendix A, figures A-80 and A-81). The coho salmon population increased dramatically during the late 1960s and early 1970s as a result of coho production from Leavenworth Hatchery. The Leavenworth Hatchery complex (Leavenworth, Naches, Methow federal hatcheries) sustained upriver runs of coho salmon until 1974. Production was then terminated because no sustaining population could be established in a local tributary stream. Since then, smaller releases have been made by Washington Department of Fisheries from the Rocky Reach mitigation rearing site on Turtle Rock (Mullan 1983).

4.2.5.1 Spring Chinook

Estimated spring chinook runs for 1970 to 1984 are shown for the Yakima, Wenatchee, Entiat, and Methow rivers in Appendix A, figure A-83, A-84, A-85, and A-86. Run sizes are estimated by adding catch, redd count expansions, and dam counts. An upward trend can be seen for the Yakima, Wenatchee, and Methow in the last several years. The Entiat spring chinook are declining in abundance.

4.2.5.2 Summer Chinook

Natural spawning escapement for the summer chinook in the Wenatchee, Methow, Okanogan, and Similkameen rivers is shown in Appendix A, figures A-87, A-88, A-89, and A-90. These counts are computed by expanding redd counts to numbers of fish (ODFW 1985b). Trends in abundance are downward for these rivers except the Similkameen which had its second highest count in 1984.

Counts of summer chinook redds in mainstem Columbia River areas between Rocky Reach and Chief Joseph Dams show a drastic decline in 1967 (Appendix A, Figure A-91) due to inundation by Wells Dam (Horner and Bjornn 1981).

4.2.5.3 Fall Chinook Salmon

In the mainstem Columbia River, the only significant fall chinook spawning occurs in the Hanford Reach. Redd counts have been conducted there each fall since 1947 (Appendix A, Figure A-92). The number of redds in the

Hanford Reach increased to over 4,000 in the 1960s, after construction of Priest Rapids Dam. This increase was probably attributable to fish spawning in the Hanford Reach that would have otherwise spawned in the area inundated by Priest Rapids Dam. Redd numbers fluctuated during the 1970s and increased again in the early 1980s to more than 7,000 in 1985 (Watson 1976, Becker 1985).

4.2.5.4 Coho

Mainstem dam counts are the only counts available for this area of the basin (see 4.3.5.).

4.2.5.5 Sockeye Salmon

The two major production areas for sockeye left in the Columbia Basin are the Wenatchee and Okanogan basins. Peak fish counts for spawning grounds are displayed for these areas in Appendix A, figures A-93 and A-94. No apparent trends are obvious from this data.

4.2.5.6 Chum

Chum are not produced in this area of the basin.

4.2.5.7 Steelhead

Mainstem dam counts are the only counts available for this area of the basin (see 4.3.5).

4.2.6 Columbia River Above Chief Joseph Dam

There are few records of fish and redd counts for the area above Chief Joseph Dam. In a survey conducted in 1938, Chapman (1943) estimated there were 800 to 1,000 chinook spawning in the mainstream Columbia in the two miles below Kettle Falls. Scholz (1985) reports annual siting of 10-20 pairs of spawning chinook in a 1/8 mile section below Meyers Falls on the Colville River from 1925-1935.

4.2.7 Snake River Below Hells Canyon Dam

Fish counts at the four Corps of Engineers dam projects on the Snake River mainstem (Ice Harbor, Lower Monumental, Little Goose, Lower Granite) show a general decline in salmon numbers during the past 20 years (See Appendix A, figures A-33 through A-48 and tables A-7 through A-10). Steelhead numbers have recently increased dramatically at these dams, after low numbers during the 1970s.

4.2.7.1 Spring Chinook Salmon

Counts of spring chinook salmon over Lewiston Dam on the mainstem Clearwater River are shown in Appendix A, Figure A-95. This dam was removed in 1972. Note that the Lewiston and South Fork dams virtually eliminated spring chinook above this point before counts began at Lewiston Dam. The overall increase in abundance was the result or improved passage facilities and a reintroduction program initiated in 1961 (USFWS 1981).

Redd counts for the Tucannon, Grande Ronde, Imnaha, Middle Fork Salmon and Upper Salmon rivers are shown in Appendix A, figures A-96, A-97, A-98, A-99 and A-100. Generally, these data shown declining tends in abundance.

4.2.7.2 Summer Chinook Salmon

Redd counts for the upper mainstem an South Fork Salmon rivers are shown in Appendix A, figures A-101 and A-102. These data shown a downward trend in abundance.

4.2.7.3 Fall Chinook Salmon

Mainstem dam counts are the only counts available for this area of the basin (see 4.2.7).

4.2.7.4 Coho

Redd counts for coho salmon in the Wallowa River are shown in Appendix-A, Figure A-103. This information indicates that run has been decimated.

4.2.7.5 Sockeye

Adult sockeye counts were taken at the Redfish Lake weir in the Salmon River Basin from 1954 to 1966 (Appendix A, Figure A-104). This data indicates a downward trend in abundance.

4.2.7.6 Chum

Chum are not produced in this area of the basin.

4.2.7.7 Steelhead

Adult summer steelhead counts for Lewiston Dam on the Clearwater River and the Washington Water and Power diversion dam on Asotin Creek are shown in Appendix A, Figure A-95 and A-105 respectively. The Lewiston Dam counts increased until the dam was removed in 1972. The Asotin Creek counts shown no different trend.

Return of summer steelhead to the Dworshak National Fish Hatchery on the Clearwater River is shown in Appendix A, Figure A-106. These data shown no trend.

Summer steelhead redd counts for the Grande Ronde River are shown in Appendix A, Figure A-107. These counts show a downward trend over time.

4.2.8 Snake River Above Hells Canyon Dam

Spring and fall chinook salmon and steelhead counts were taken at Brownlee-Oxbow dam complex from 1957 through 1963 (Appendix A, Figure A-108). During these years, wild runs produced above the dams were being eliminated. The counts of fish indicate natural production above the dams at the time of construction. Maximum counts were approximately 17,000 fall chinook in 1958, 2,600 spring chinook in 1960, and 4,500 steelhead in 1959 and 1960 (Haas 1965).

4.3 COLUMBIA BASIN SALMON AND STEELHEAD HABITAT

4.3.1 Overview

Salmon and steelhead have specific habitat requirements, including access to and from the sea; an adequate supply of clean, cool water; suitable gravel for spawning and egg incubation; and an ample supply of food and space for rearing juveniles. Salmon and steelhead habitat quantity and quality have changed dramatically in the Columbia River Basin since 1850. Table 15 shows habitat quantity in miles of stream available for spring, summer, and fall chinook, coho, and chum salmon and steelhead for predevelopment times and for 1975. This table also displays estimates of smolt outmigrants for 1985. Sockeye salmon production areas are displayed in Appendix B, Table B-2. Information on changes in the quality of habitat are discussed for each of the six areas identified in Table 13 in this section and in Sections 5.3-5.9.

Prior to development, over 163,000 square miles of salmon and steelhead habitat existed in the Columbia River Basin (Thompson 1976b). This habitat figure represents approximately 14,666 miles of stream; 11,741 miles above and 2,925 miles below Bonneville Dam respectively. In 1976, only 72,800 square miles of the basin or 10,073 miles of stream remained accessible to

Table 15 - Salmon and steelhead habitat in the Columbia River Basin.[1]

	Habitat Available[2] (miles of stream)			Estimated Smolt Produced[4]
	Formerly[3]	1975	% Loss	
Columbia River below Bonneville Dam				
Spring chinook	1,835	1,191	35	
Summer chinook	0	0	0	
Fall chinook	861	1,047	(22)[5]	
Coho	1,319	2,124	(61)[5]	
Chum	309	194	37	
Steelhead	2,410	2,378	1	
All Species				
Columbia River between Bonneville Dam and its confluence with the Snake River				
Spring chinook	1,218	655	46	
Summer chinook	0	148	148	
Fall chinook	70	201	(187)	
Coho	231	344	(49)	
Chum	0	0	0	
Steelhead	1,834	1,479	19	
All Species				14,771,00
Columbia River above its confluence with the Snake River				
Spring chinook	1,801	758	58	
Summer chinook	909	286	69	
Fall chinook[6]	485	115	76	
Coho	523	361	31	
Chum	0	0	0	
Steelhead	1,485	938	37	
All Species				22,450,000
Snake River below Hells Canyon Dam				
Spring chinook	3,899	2,813	28	
Summer chinook	2,198	1,834	17	
Fall chinook	674	345	49	
Coho	481	379	21	
Chum	0	0	0	
Steelhead	5,156	4,120	20	
All Species				8,951,000
Snake River above Hells Canyon Dam				
Spring chinook	1,865	0	100	
Summer chinook[6]	1,865	0	100	
Fall chinook	371	0	100	
Coho	0	0	0	
Chum	0	0	0	
Steelhead	2,050	0	100	
All Species				0

Source: Pacific Northwest Regional Commission (1976).

[1] Predevelopment and early 1960s sockeye salmon habitat is documented in Appendix B, Table B-2.

[2] Habitat refers to natural spawning and rearing areas.

[3] "Formerly" refers to the time before water developments blocked access to streams and before habitat was degraded (pre-1850).

[4] Numbers of smolts estimated for 1985 outmigration by Mainstem Passage Advisory Committee of the Northwest Power Planning Council. Includes hatchery and naturally produced smolts.

[5] Fishway at Willamette Falls constructed in 1971 increased habitat in the Willamette Basin.

[6] Mainstem Columbia River spawning habitat has been added to the Pacific Northwest Regional Commission (1976) estimates.

anadromous fish; 7,582 miles above and 2491 miles below Bonneville Dam respectively (Pacific Northwest Regional Commission 1976). This is a decrease of 4,593 miles of habitat which represents about a 31 percent decrease from predevelopment times.

Figure 5 depicts the area formally available to salmon and steelhead in predevelopment times and area available presently. Maps that precisely delineate habitat by species were prepared by Fulton (1968, 1970) and are available for review in the Council public reading room. Present and former spawning areas for Columbia River Basin salmon and steelhead are summarized in Appendix B.

4.3.2 Columbia River Below Bonneville Dam

A major physical barrier to anadromous fish in the Willamette River occurs at Willamette Falls which is about 42 feet high (Willis, Collins, and Sams 1960). A fishway, completed in 1971, improved passage above the falls for spring chinook, winter steelhead and coho. The fishway made habitat above the falls accessible to fall chinook and summer steelhead (Bennett 1985). Numerous other natural falls in the Willamette drainage block fish passage to otherwise suitable spawning and rearing areas. Dams constructed on tributaries above Willamette Falls have blocked about 250 miles of stream to salmon since 1950. Reservoir operations have flooded or dredged spawning areas and raised water temperatures.

Water quality deteriorated in the Willamette River until the mid-1960s. Pollutants included fine sediments, sawmill and cannery wastes, raw sewage, and sulphite pulp liquor. At times, the river was so polluted by the time it reached Portland that salmon and steelhead would not migrate upstream. Since that time, the Willamette's water quality has been restored through treatment of industrial and municipal effluent and controlled release of reservoir storage capacity.

Virtually all of the spring chinook habitat below Bonneville Dam, outside of the Willamette River, has been destroyed or is now inaccessible. Major losses have occurred in the Lewis and Cowlitz Rivers as the result of hydro developments. In addition, the eruption of Mount St. Helens in 1980 removed much of the Toutle River watershed from fish production.

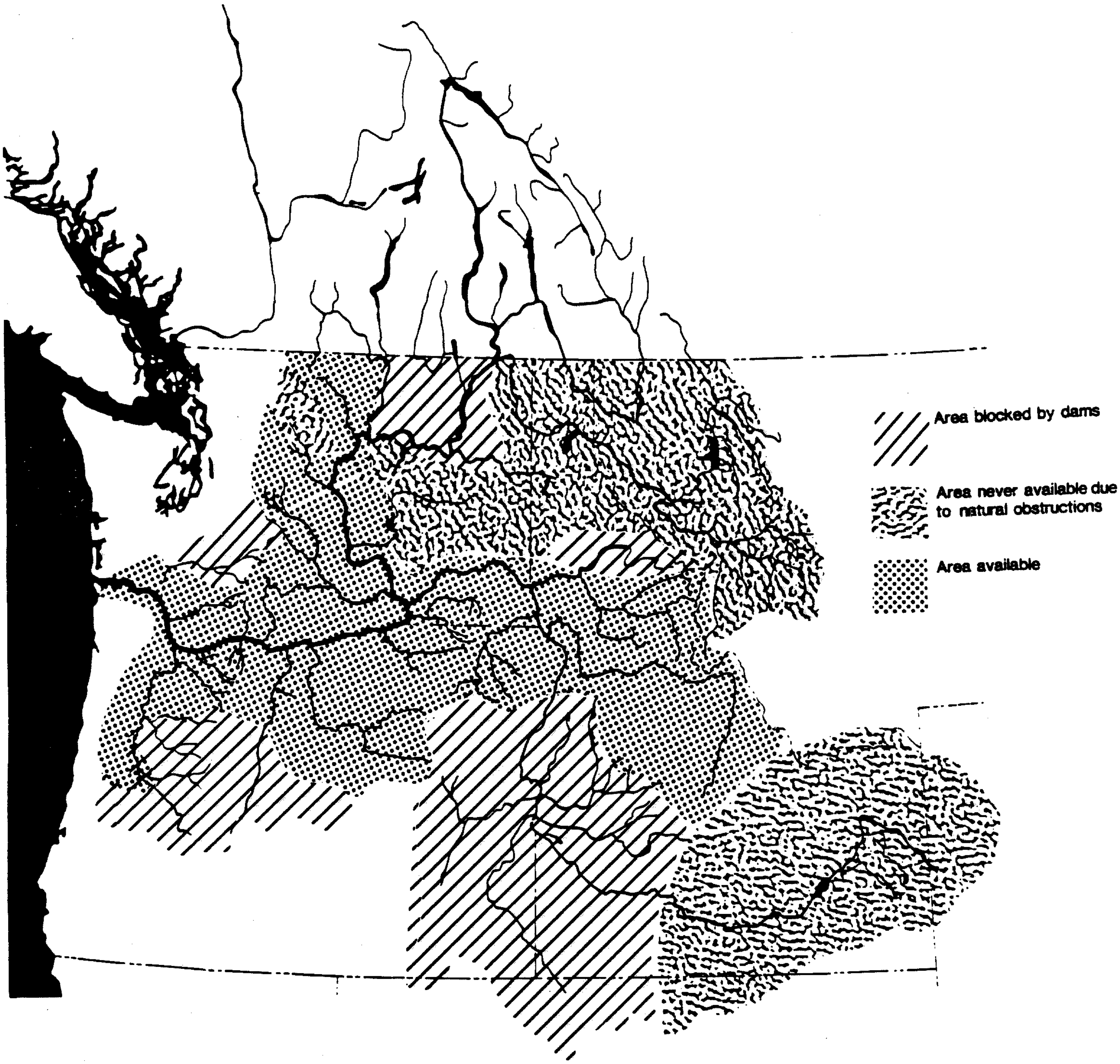

Figure 5. Columbia River Basin Anadromous Fish Areas (Northwest Power Planning Council 1984).

4.3.3 Columbia River Between Bonneville Dam and Its Confluence with the Snake River

The mainstem Columbia River behind where the John Day and McNary dam pools now stand was spawning habitat for fall chinook. Inundation by these dam backwaters eliminated production for fall chinook in this stretch of the mainstem.

The John Day River system provides spawning and rearing habitat for anadromous salmonids, principally steelhead. Steelhead are well distributed throughout the upper part of the basin (Oregon State Water Resources Board 1962). Spring chinook salmon are limited to the upper North and Middle Forks and to the mainstem of John Day River. Coho and fall chinook salmon are minor species in the drainage.

Habitat degradation, primarily water flow depletion, has limited salmonid productivity in the Umatilla and Walla Walla drainages.

4.3.4 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

The mainstem Columbia River was formerly an important spawning area and an important migration route for salmon and steelhead. Aerial surveys conducted in 1946 showed that chinook salmon used gravel areas throughout the 210-mile reach from the confluence with the Snake and Okanogan rivers (Bryant and Parkhurst 1950). The only remaining fall chinook and steelhead spawning habitat in this stretch is a 50-mile portion known as the Hanford Reach that lies between Priest Rapids Dam and the upper extreme of the McNary Dam reservoir (PFMC 1979).

The Yakima River is one of the largest tributaries of the Columbia River. Prior to the initial development of the Yakima Valley in about 1860 (Davidson 1953), this river system provided extensive spawning and rearing areas for chinook, coho, and sockeye salmon (Bryant and Parkhurst 1950). The lower 29 miles of the Yakima River were seldom used for spawning. Most salmon tended to ascend farther upstream to the reach from Ellensburg to Easton Dam where most spawning still occurs. The system was formerly an important steelhead stream and still supports a small run (Bryant and Parkhurst 1950).

Go To Next Part

Go To Next Part

Bryant and Parkhurst (1950) reported that from 1935 to 1947 most salmon spawning in the Wenatchee River occurred in the upper nine miles below the outlet of Lake Wenatchee. This area is a relatively unimportant segment of the Wenatchee Basin spawning grounds today. Most of the spring chinook spawn in tributaries (Nason Creek, Little Wenatchee, Chiwawa River) while large numbers of summer chinook spawn downstream from Tumwater Canyon. A large run of coho salmon formerly (before the early part of the 20th century) spawned in the Wenatchee River. Of the few coho that presently migrate above Rock Island Dam, most are the result of the hatchery program at Turtle Rock, above Rocky Reach Dam. Few of these are known to move into the Wenatchee to spawn. The Wenatchee and Okanogan River drainages became the major production areas for sockeye salmon in the Columbia River system after Grand Coulee Dam was constructed in 1939 (Mullan 1984). The Wenatchee River also supports a run of steelhead.

The Okanogan River has the greatest amount of available habitat for sockeye salmon in the entire Columbia River system. Sockeye use Lake Osoyoos and about eight miles of the river immediately above the lake for rearing and spawning (Bryant and Parkhurst 1950).

Important steelhead and spring chinook habitat also occurs in the Entiat, Methow, and Okanogan drainages (ODFW 1984c).

4.3.5 Columbia River Above Chief Joseph Dam

The Columbia River extends north into Canada about 300 miles amid steep mountain ranges. It then loops back (the Big Bend) in a southerly direction for nearly 200 miles to its point of origin in Columbia Lake. Salmon were known to have ascended to within a few miles of this lake (Bryant and Parkhurst 1950). Before 1939 (when Grand Coulee Dam was constructed) the Columbia River was a fast-flowing river between Kettle Falls and Grand Coulee Dam, a distance of 103 river miles. Chinook (presumably summer) salmon reportedly spawned in great numbers on gravel bars in the main river just below Kettle Falls from June to October. They also spawned near the mouths of several nearby tributaries (Bryant and Parkhurst 1950). Kettle Falls was flooded by Grand Coulee Dam.

The Arrow Lakes occupy deep, glaciated river valleys and together are about 100 miles in length and over two miles wide. Sockeye salmon reportedly ascended to the Arrow Lakes region (Bryant and Parkhurst 1950).

The plateau section above the Big Bend was the first area in the Canadian segment of the Columbia River where spawning took place. Suitable spawning areas were lacking in the river reach immediately downstream (Bryant and Parkhurst 1950). Fish using this section of the river were probably summer chinook.

Salmon also spawned in the Kettle, Pend Oreille, Kootenai, Sanpoil, Nespelem, Colville, and Spokane rivers.

4.3.6 Snake River Below Hells Canyon Dam

The Snake River is the largest tributary to the Columbia River. Prior to 1850 this drainage provided an estimated 7,206 miles of habitat for salmon and steelhead (Table 15).

A high falls located about six miles above the mouth of the Palouse River renders this stream inaccessible to migratory fish.

Parkhurst (1950a) reported that in 1935 the Tucannon River had numerous good shallow riffles and an adequate number of resting pools well distributed throughout its length. A significant portion of this river that once contained excellent salmon spawning habitat has been severely degraded by poor agriculture and grazing practices.

The gradient of Clearwater River is generally moderate throughout most of its course. Parkhurst (1950a) reported that seven percent of the stream bed was suitable for spawning in 1938. The North Fork Clearwater was totally blocked to upstream migration in 1971 with the construction of Dworshak Dam.

Prior to the early 1900s, the Grande Ronde River drainage was an important producer of salmon and steelhead. Parkhurst (1950a) reported that in 1940-41 the lower mainstem Grande Ronde River had a moderate gradient with numerous shallow riffles and an adequate number of resting pools. The middle segment of the river had extensive spawning areas. Excellent spawning habitat also was reported for a distance of two miles in the upper segment up to Starkey, Oregon. Production habitat is not limited to the mainstem areas, but includes a number of tributary streams such as the Wenaha, Lostine, Minam rivers and Lookingglass Creek (Thompson and Haas 1960).

The mainstem Salmon River extends for about 400 miles in Idaho. The lower 200 miles has a fairly steep gradient and little suitable spawning area. Parkhurst (1950b) reported that in 1941 the stream bed was heavily silted for about 161 miles from Shoup to Stanley, Idaho. Above Stanley, he observed excellent spawning habitat for about 35 miles. Also, numerous small side channels were present to serve as natural rearing areas for salmonid fry. Conditions in this stretch of the river are currently far different. The reach between the Middle Fork (about 15 miles below Shoup) and the Lemhi River now contains a substantial amount of available gravel. Broad riffles near the mouth of Warm Springs Creek support a substantial portion of the summer chinook spawning in the Salmon River (IDFG 1985). Spring and summer chinook and sockeye salmon, and steelhead use this drainage.

The South Fork Salmon River is a major tributary of the Salmon River. About two-thirds of the river is riffles, the remainder pools. Prior to 1962, when logging production increased, the South Fork contained Idaho's largest summer chinook salmon run (Platts and Megahan 1975). This tributary also supports a steelhead population. Large increases in sediment load resulting from logging operations and road construction in the mid-1960s reduced spawning areas.

The Middle Fork of the Salmon River is also a good producer of spring chinook salmon and steelhead. The major portion of this drainage runs through an undeveloped wilderness area.

The Lemhi River enters the Salmon River at Salmon, Idaho. Parkhurst (1950b) reported a moderate gradient throughout the Lemhi, with abundant, well distributed spawning habitat of excellent quality. The Lemhi River formerly supported a large run of chinook salmon and steelhead. The stream produces few salmon presently.

The Imnaha River is about 75 miles long and flows through an extremely rugged, mountainous area. The gradient is relatively steep throughout its course. The drainage has a large amount of rearing habitat for anadromous salmonids. Most of this habitat is in good to excellent condition (James 1984). Imnaha Falls, located about 65 miles above the mouth, is reported to be a barrier to salmon (Parkhurst 1950b). Salmon and steelhead habitat in the Imnaha River drainage has suffered only minor degradation.

4.3.7 Snake River Above Hells Canyon

Hells Canyon Dam is the lowest block to upstream migration to major spawning areas in the upper Snake Basin, including the mainstem Snake, Weiser, Payette, Powder, Boise, Owyhee, and Malheur rivers.

Irving and Bjornn (1981) report that over 95 percent of the fall chinook in the Snake River in 1959 and 1960 used habitat upstream from the Hells Canyon Dam site.

Before agricultural development of the basin started in 1931, the Weiser River system was a valuable spring chinook salmon producer. Extensive spawning areas in the mainstem and its principal tributaries were noted in 1941 by Parkhurst (1950b).

The Payette River system was an important spawning and rearing area for spring chinook and sockeye salmon and steelhead before 1900 (Parkhurst 1950b). Large amounts of sockeye salmon spawning and rearing occurred in the lakes in its headwaters. Black Canyon Dam, constructed in 1924 at river mile 39, blocked the entire run of sockeye salmon from the headwater lakes and confined the spring chinook salmon and steelhead runs to the mainstem below the dam (Parkhurst 1950b; Idaho Power Company 1985).

The Powder River mainstem was an excellent salmon stream before agricultural and mining developments resulted in habitat damage in the early 1900s. Parkhurst (1950b) reported that in 1942 less than 10 percent of the streambed was suitable spawning habitat in the lower river because of siltation. The Boise, Owyhee, and Malheur rivers also supported populations of spring chinook salmon.

Chapter 5
CAUSES OF DECLINES IN FISH RUNS AND HABITAT FROM 1850 TO THE PRESENT

5.1 INTRODUCTION

5.1.1 Overview

This chapter contains information pertaining to fishing, hydropower, irrigation, logging, mining, grazing, agriculture, and other activities that harm Columbia Basin salmon and steelhead.

How each type of activity detrimentally affects Columbia Basin salmon and steelhead cannot be ascertained with certainty by collecting numerical data alone. As stated by the Salmon and Steelhead Advisory Commission (1984), "this problem can be described very simply: Destruction and degradation of (spawning, rearing, and migration) habitat has drastically reduced the production of salmon and steelhead and the remaining production frequently has been overfished. These 'simple' problems act in synergy in ways so complexly interrelated it is frequently impossible to isolate cause and effect." This makes it difficult to quantitatively identify and separate the individual causes of salmon and steelhead loss in the Columbia Basin. However, a display of information describing the various detrimental activities can help overcome some of these difficulties and lead to a better evaluation of loss.

The information is organized in a chronological order so each detrimental activity can be traced through time and the magnitude of its effects on salmon and steelhead can be investigated. Where feasible, the information is also organized into the six geographic areas identified in Table 14. The information includes qualitative descriptions and, for each activity, at least one quantitative indicator of the magnitude of the activity over time. Not all the information directly relates to the severity and magnitude of the activity on salmon and steelhead, but is included to aid in measuring the general magnitude of an activity and its possible or probable effect on salmon and steelhead. The quantitative indicators are frequently limited to only a portion of the period from predevelopment to now because that is the extent of the information available. Site specific information, organized into the six areas identified in Table 14, is compiled in Appendix D.

All of the activities described in this compilation have been individually and collectively harmful to Columbia Basin salmon and steelhead to some extent. The amount of harm attributable to any specific activity has not been determined in this compilation. However, the information could be used to help determine the relative contributions of the harmful activities identified. The Council intends to make such a determination about effects of hydropower operations on Columbia River Basin salmon and steelhead.

5.1.2 Summary of Detrimental Activities

Development of the Columbia River Basin has resulted in considerable harm to salmon and steelhead. The earliest identified negative human impact was fishing. Early harvest focused on chinook; when the chinook harvest declined after 1884, emphasis shifted to steelhead and sockeye (1890-1900), followed by chum and coho (1920s). By 1945, all species had declined significantly.

Other impacts closely followed fishing. By 1900, mining had become important in areas of Oregon, Washington and Idaho. By 1925, there were major increases in land devoted to agriculture, and there were also major advances in irrigation and logging as well. By 1941, large hydropower projects (Rock Island, Bonneville and Grand Coulee dams) had been built. The period 1940-1965 saw major increases in logging and water storage for a variety of purposes including hydropower generation and irrigation.

The following summarizes the detailed information found in this chapter. For purposes of comparison, some of the summary information included refers to fish run data found in Chapter 3. Note that the two lower Columbia River areas and the two Snake River area analyses have been combined in this summary due to difficulties in separating some of the data for these areas.

Logging has been more extensive in the lower Columbia River area than in any other area. The Willamette River drainage has been particularly affected. Early logging practices resulted in sedimentation of spawning areas, blockage of migration by log and log debris dams, and degradation of water quality. Extensive logging was underway in the lower river by 1925.

Agriculture is another important factor in the lower river. Major increases in land devoted to agriculture occurred by 1930. Some specific locations strongly affected by irrigation include the Umatilla, John Day, McKenzie, Deschutes, Walla Walla, Hood, Santiam, and Touchet subbasins.

5.1.2.2 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

Logging has contributed to salmon and steelhead loss in the Middle Columbia area. Logging reached its peak in this area in 1968-69.

Irrigation diversions also have contributed to losses in the Middle Columbia area. They are the primary factor affecting salmon and steelhead runs in the Yakima River Basin; for example, reduction of runs occurred during the 1890-1905 expansion of irrigation in the area. The Okanogan, Methow, and Wenatchee river basins also are affected by irrigation.

Hydropower development had a clear effect on salmon in the Middle Columbia area. Construction of Wells Dam in 1967 caused inundation of summer chinook spawning habitat, and was followed by reduced redd counts.

5.1.2.3 Columbia River Above Chief Joseph Dam

The Upper Columbia River area has been affected little by logging, and less by agriculture and irrigation than other subregions. The major detrimental impacts have resulted from dam construction, including that associated with hydropower generation.

5.1.2.4 Snake River Area

Extensive logging in the Snake River area was initiated about 1963. Historically, irrigation always has been heavier in the Snake River area than in the other three areas. By 1947, the Snake River had nearly twice as much water diverted for irrigation as any other area. At present, nearly half the total water diverted in the Columbia River Basin is in the Snake River area.

Dam construction has strongly affected Snake River salmon and steelhead even though hydropower generation and storage capacity has been less extensive than for the Upper Columbia area. Upstream migration, once blocked at Shoshone Falls, is now blocked for a major portion of the basin by Hells Canyon Dam. In addition, the four hydropower dams in the lower Snake led to the inundation of considerable spawning habitat.

5.2. FISHING

5.2.1 Overview

Commercial fishing on the Columbia River was already an industry by 1861, when Rice and Reed began packing salted salmon 60 miles below Portland (Craig and Hacker 1940). The rapid expansion in the cannery industry reflected an expanding commercial fishery. This held until 1882, when packers noted a decline in salmon and expressed concern about the depletion of the runs on the Columbia River (Craig and Hacker 1940). It is generally accepted that harvest rates contributed to the decline in catches at that time (Beiningen 1976a).

The use of Columbia River salmon and steelhead has undergone great change. As the numbers of white settlers increased, the numbers of Indians and their catches decreased. Initially, the non-Indian catch was entirely within the lower Columbia River and was primarily commercial. In 1912, the ocean troll fishery began competing with the river fishermen. Sport fisheries were not extensive until after World War II, and did not become important until the 1950s (Wendler 1960).

The contributions of different salmon and steelhead stocks to the various fisheries depends in great part on the migration path of the fish. Columbia River chinook salmon exhibit at least two contribution patterns according to recoveries of tagged fish from various locations along the Pacific Coast (Table 16). Fishery managers assume the migration path of tagged chinook salmon represents similar untagged hatchery and wild fish. Columbia River upriver summer chinook, upriver bright fall chinook, and Willamette River spring chinook salmon migrate far to the north and contribute substantially to the troll fisheries in southeastern Alaska, northern British Columbia, and Vancouver Island. Current data suggests upriver spring chinook salmon do not contribute significantly to ocean fisheries. While in the past these upriver stocks made substantial contributions to inriver Indian and non-Indian fisheries, in recent years the runs have been so depressed that traditional fisheries have been closed or severely restricted.

Willamette River spring chinook salmon also appear to have a northerly migration pattern. Unlike the upriver stocks, however, they currently support a large inriver sport fishery and contribute to a limited mainstem commercial fishery.

Table 16 - Percentage distribution of Columbia River chinook among coastal fisheries.[1]

Catch Area	Willamette Springs[2]	Cowlitz Springs[3]	Upriver Springs[4]	Upriver Summer[5]	Fall Tules[6]	Fall Brights[7]
S.E. Alaska	14.0	1.0	0.0	19.8	0.3	23.6
British Columbia						
North	26.6	--	--	13.5	0.8	16.3
Central	2.8	--	--	6.5	0.8	6.2
W. Vancouver Is.	12.7	--	--	18.0	19.9	16.1
Inside areas	1.2	--	--	1.0	4.3	2.0
Total British Col.	43.3	22.9	9.3	39.0	25.8	40.6
Washington/Oregon						
Coastal	5.4	48.0	--	--	39.2	--
Other areas	0.6	1.7	--	--	0.6	--
Total WA/OR	6.0	49.7	1.9	4.0	39.8	3.2
Total Ocean	69.3	73.6	11.2	62.8	65.9	67.4
River Return						
Harvest	12.7	1.4	4.1	0.3	10.7	7.9
Escapement	24.0	25.0	84.8	37.0	19.0	10.6
Total River Return	36.7	26.4	88.9	37.3	29.7	18.5

Source: Columbia River Inter-Tribal Fish Commission (1984).

[1]Catch distribution is subject to change year to year depending on regulations set to allocate catch based on abundance of fish runs, previous years catch, and international and Indian treaties.

[2]Average of recoveries from six tag codes placed on 1976 brood March releases. River return harvest and escapement from Bennett 1984.

[3]Average of recoveries from 15 tag codes placed on 1971 and 1972 brood releases.

[4]Average of recoveries from 11 tag codes placed on 1971 and 1972 brood releases.

[5]Washington Department of Fisheries catch model simulation of 1981 fishing regulations.

[6]Washington Department of Fisheries catch model input data.

[7]Includes small amounts of mixed U.S. and Canadian catches.

The second distribution pattern is typified by the Cowlitz River spring chinook and tule fall chinook salmon, which exhibit a relatively local migration pattern. These stocks are harvested primarily in the Vancouver Island troll and Washington ocean sport and troll fisheries, and support inriver commercial and sport fisheries.

The distribution of coho in the ocean is fairly stock-specific. The "early" stock shows a strong southerly migration while the "late" stock moves primarily to the north. Both stocks are harvested concurrently in the commercial fisheries with fall chinook in the river. There are, however, specific target fisheries on coho (and chinook) in the ocean. In recent years large numbers of coho are taken in the river recreational fishery at the mouth of the river. Relatively few are harvested in the river outside of that area. Once the coho enter the tributary streams, they are again the target of recreational fisheries.

Sockeye salmon, chum salmon, and steelhead contribute primarily to the inriver sport and commercial fisheries. Sockeye salmon are harvested while summer chinook and summer steelhead are present. Steelhead are caught incidentally in commercial fisheries set to harvest other species in August and September.

Many of the fisheries on Columbia River Basin salmon and steelhead simultaneously harvest fish produced by the six areas identified in Table 14. The ocean fisheries and the mainstem Columbia River fisheries below the confluence with the Snake River are two such examples. For this reason, the fisheries in these areas are presented independently of the Table 14 regional breakdown.

5.2.2.1 The Ocean Fisheries

Commercial trolling (towing hook and line behind a boat) for chinook and coho salmon began off the mouth of the Columbia River in 1912 (Craig and Hacker 1940). About 500 boats trolled in this area in 1915, and by 1919 the number of boats had more than doubled (Craig and Hacker 1940). The boats were small and inefficient compared with the larger ocean-going vessels that began to appear in the 1920s (Van Hyning 1951). Until the early 1930s, trolling occurred near the mouth of the Columbia River. After discovering that salmon could be caught in greater numbers on their feeding grounds, trollers moved farther offshore (about 25 miles) (Smith 1979; Craig and Hacker 1940).

Early catch records are not available because licenses for hook and line fisherman were not required before 1917. It is known, however, that prior to 1917, fairly large numbers of chinook and silver were being taken and the first fairly reliable catch records for 1917 showed that 48,782 chinook and 75,211 silver were taken by licensed trollers (Kauffman 1951).

From 1936 to 1960, trends in fall chinook landings varied depending on the area fished (Van Hyning 1973). Central Oregon coastal landings increased until 1957, then declined sharply. Landings off the Columbia River (Oregon and Washington) increased until 1952, then gradually declined. The Washington coastal area landings increased rapidly until 1955, then declined sharply. Landings for the west coast of Vancouver Island gradually increased until 1948, sharply increased until 1959, and then declined. Both northern British Columbia and southeastern Alaska have had long-term declines (Van Hyning 1973). Trends for three geographically related areas that include Oregon, Columbia River, and the Washington Coast showed increased landings followed by a decline. Van Hyning (1973) suggests that stocks in this area were unable to withstand the high level of catches in the early and mid-1950s. With the exception of the Alaskan catch, the ocean commercial harvest of fall chinook and coho salmon increased from the early 1960s to mid-1970s (Beiningen 1976a). Since 1976, however, ocean trolling and landings have been significantly reduced. Washington troll effort for all areas off the coast peaked in 1976 with 58,900 days fished, but declined to 1,100 days fished in 1984. Chinook catch by the Washington non-treaty troll fleet declined from 335,200 in 1976 to 9,000 in 1984. Washington troll-caught coho declined from 1,347,300 in 1976 to 23,400 in 1984 (PFMC 1985a).

A marked decrease in the average age of fall chinook caught by the commercial ocean fishery is evident when comparing the period 1919-1930 to 1949-1963 (Van Hyning 1973). These comparisons were based on samples from the Columbia River to northern British Columbia, an area where Columbia River chinook are abundant. In the later period, young fish comprised a larger portion of the landings, while older fish virtually disappeared. Average size also decreased. These trends are typical of an overexploited population and indicate that the ocean fishery significantly affected chinook populations (Van Hyning 1973).

Ocean sport fishing for salmon developed off the mouth of the Columbia River during the 1950s (Wendler 1960). Prior to 1951, the fishery at the mouth of the Columbia River was entirely in the estuary and consisted mainly of mature chinook salmon (Van Hyning 1973). This fishery operated during the peak of the fall chinook run between mid-August and early September. After 1951, the sport fishery moved offshore, and coho salmon and immature chinook salmon became an important component of the catch. The estimated annual ocean sport chinook harvest increased from about 35,000 fish in 1949 to nearly 130,000 fish in 1956, then leveled off at about 100,000 fish (Van Hyning 1973). Fishing effort (trips) also increased during this period, from about 80,000 to over 400,000 per year. From 1960 to 1975, the ocean sport catch of fall chinook and coho salmon continued to increase in all areas (Beiningen 1976a). This rise in ocean sport catches reflects both rapid expansion of the fishery and larger numbers of fish from expanding hatchery operations (Chaney and Perry 1976). Ocean sport catches declined since 1976 as more restrictive fishing regulations were enacted. For example, in 1984, the Washington ocean recreational catch of chinook was only 7,000 for all areas off the coast compared with 170,700 in 1976 (PFMC 1985a).

Ocean fishing also caused mortalities of small chinook salmon caught, then released by trollers. For example, in 1957, when over one million chinook were landed in the troll fishery from central Oregon to Vancouver Island, trollers released an estimated additional 250,000 chinook, of which 100,000 may have died. Van Hyning (1973). To account for hooking mortalities, harvest managers multiply the landed catch of chinook and coho by 1.04-1.10 to obtain an estimate of the number of legal-sized fish killed in the fishery but not landed (Mongillo 1984).

5.2.2.2 Mainstem Columbia River Fisheries Below the Confluence with the Snake River

A major Indian dip net (hand held nets with long handles dipped into the water from strategic positions along the shore) fishery was located at Celilo Falls on the Columbia River until 1957 when The Dalles Dam pool inundated the falls. While Indians fished many parts of the Columbia River watershed, they were particularly numerous at Celilo Falls. Catch records show an increase in chinook and steelhead catches from 1928 to the early 1940s, with a subsequent slight overall decline in chinook landings and a relatively stable catch for steelhead until 1957 (Figure 6). A year-round dip net fishery still exists in the area between Bonneville and McNary dams known as Zone 6 (Figure 7), but catches are small (Edwards 1985).

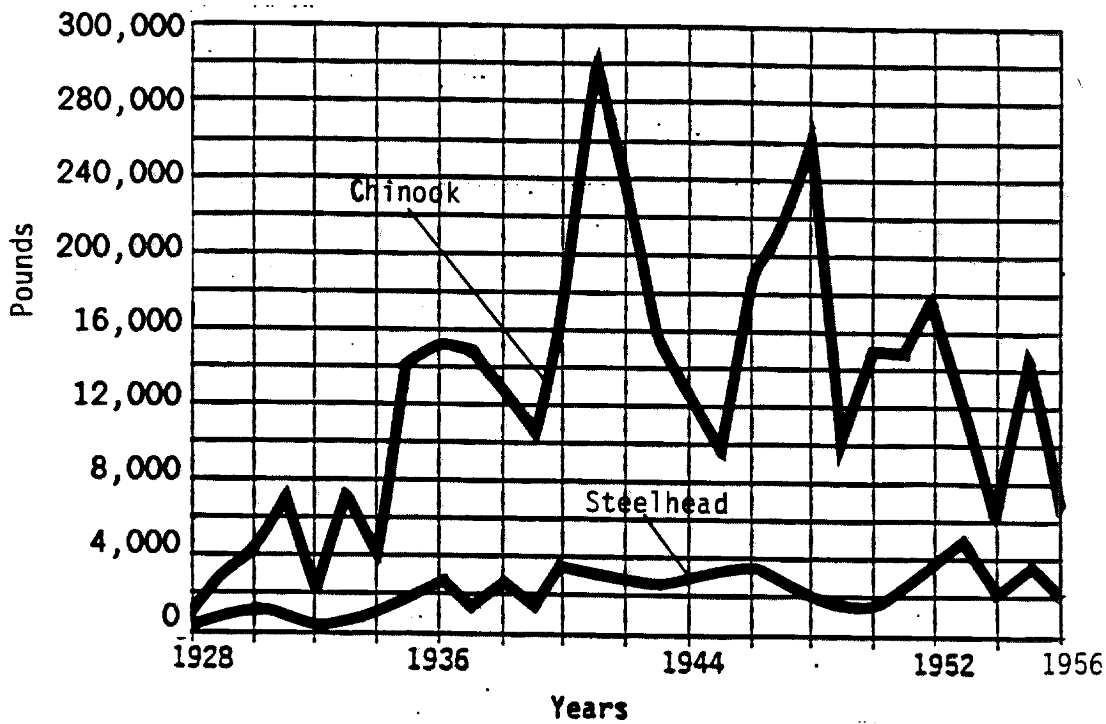

Figure 6. Celilo Falls Indian dip net landings (Schoning, Merrill and Johnson 1951; Fish Commission of Oregon and Washington Department of Fisheries 1972).

After Celilo Falls was inundated, the Indian fishery changed gear type from primarily dip net to primarily set gill net (nets anchored in the water that catch fish by the gills). Indian catches in Zone 6 rapidly increased from a low of 4,500 fish in 1960 to a high of about 150,000 fish in 1975 and 1976 each as shown by Figure 8 (see also Appendix A, Table A-2). This result reflects both increased effort by Indian fishermen and federal court decisions interpreting the rights of Indian tribes to specific shares of the resource. Depressed stocks resulted in a decline in Zone 6 catches to a low of about 45,000 fish in 1983 (ODFW 1985a). In 1984, increased returns of steelhead and sockeye once again bolstered the total catch in Zone 6 to over 150,000 fish.

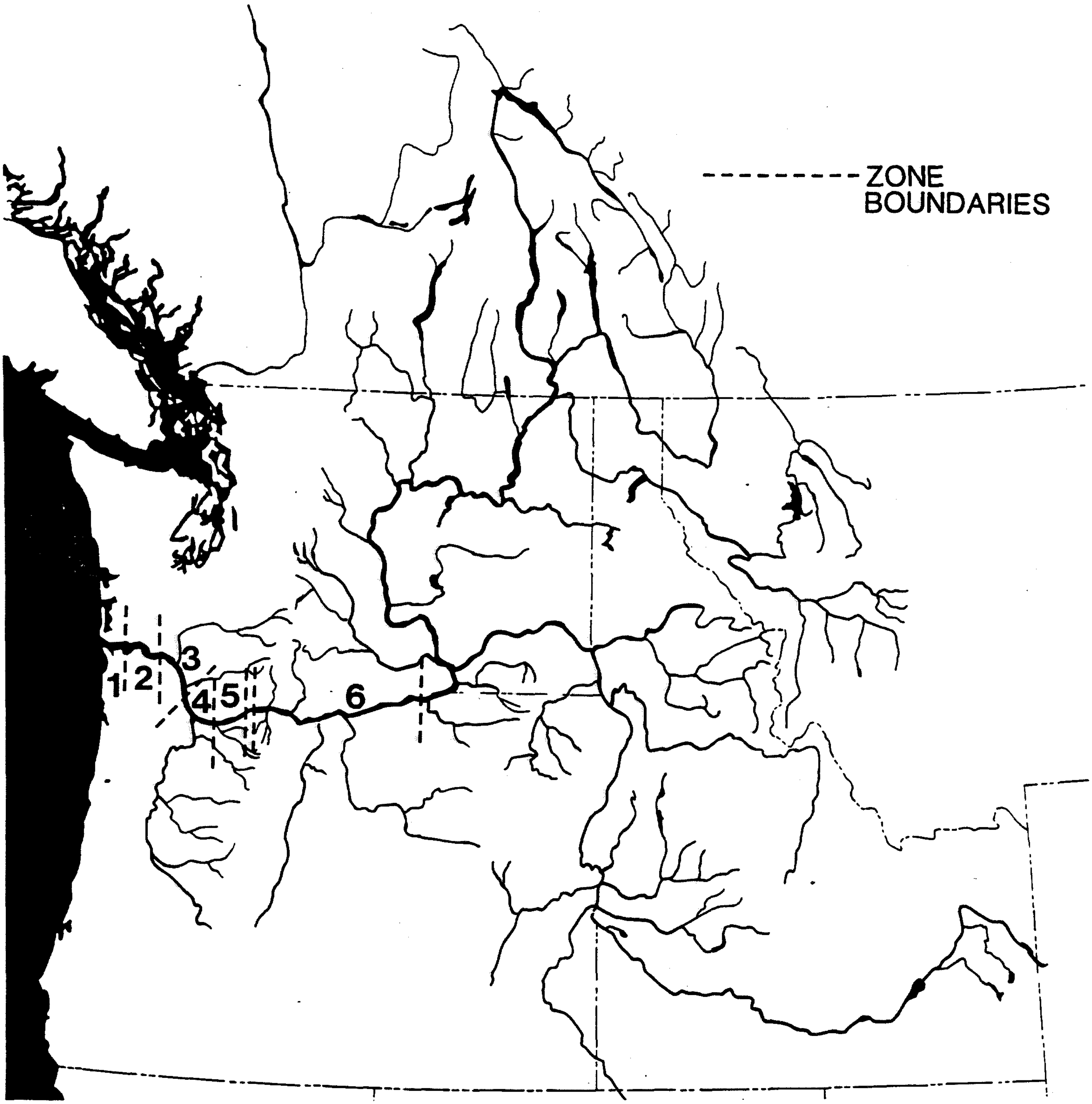

Figure 7. Commercial Fishing Zones in the Columbia River Basin

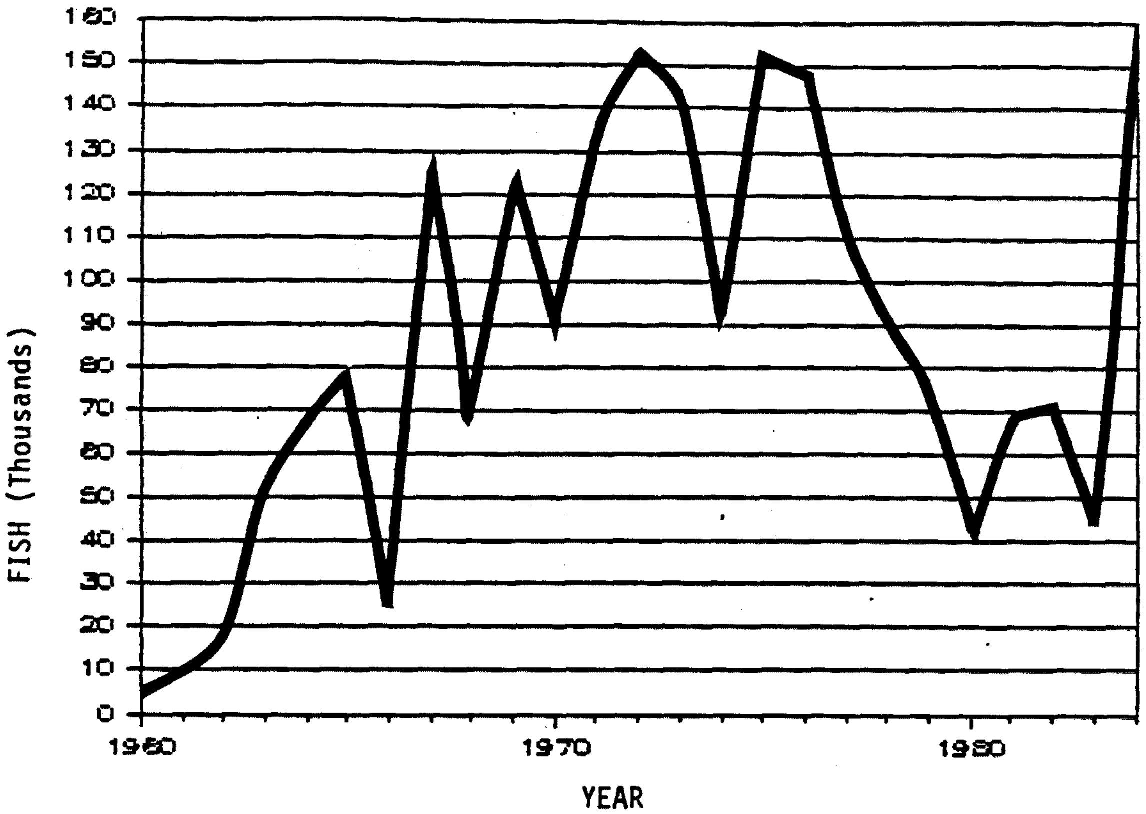

Figure 8. Columbia River commercial Indian catch of salmon and steelhead (ODFW 1985a).

Commercial landings of chinook salmon in the lower Columbia River (below the mouth of the Deschutes River until 1957, below Bonneville Dam after 1957) have been recorded since 1866 (Figure 9). These numbers represent only the amount of fish caught in the lower river and therefore generally do not include ocean harvest and escapement past the lower river commercial fishery (note that catch includes some coho troll catch, partly of origins outside the Columbia Basin). Prior to 1880 fishermen concentrated on harvesting summer chinook in this fishery. By the end of the 1880s, noticeable declines in summer chinook led fishermen to shift their efforts to spring and fall chinook and then to other salmon species and steelhead by 1889 (Beiningen 1976a). Peak commercial catches of chinook and coho occurred in 1883 and 1925, respectively (Craig and Hacker 1940). In general, a relatively steady decline in lower Columbia River commercial landings has occurred since the 1920s for all species (see Appendix A, Figures A-1 through A-12). Commercial landings for all species are tabulated in Appendix A (Table A-1).

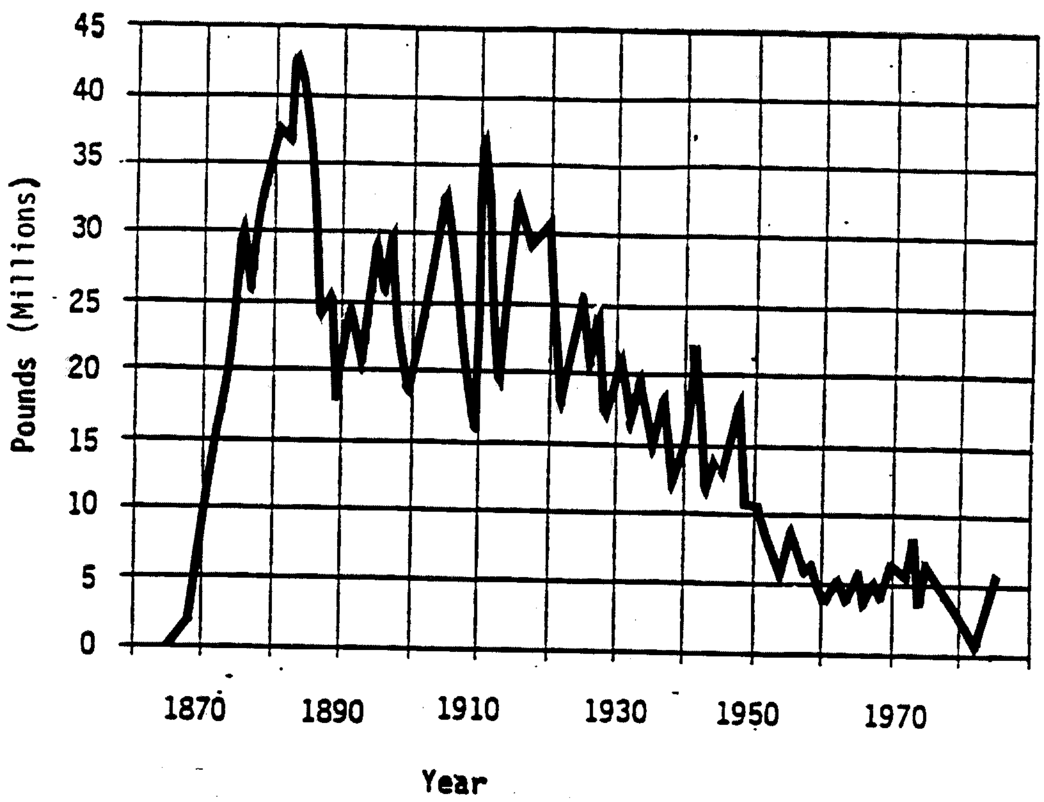

Figure 9. Commercial landings of chinook salmon in the Columbia River (Cleaver 1951; Beiningen 1976a; ODFW 1985a).

Currently, commercial fishing occurs in the lower Columbia River below Bonneville Dam, with special closed areas to protect fish at dams, at the mouths of certain tributaries and adjacent to hatcheries. The commercial fishery area below Bonneville Dam is fished using drift gill nets (nets drifted through the water that catch fish by the gills). The percentage of the spring chinook run harvested by commercial fisheries on the lower mainstem is depicted in Figure 10. A decline in catch is evident.

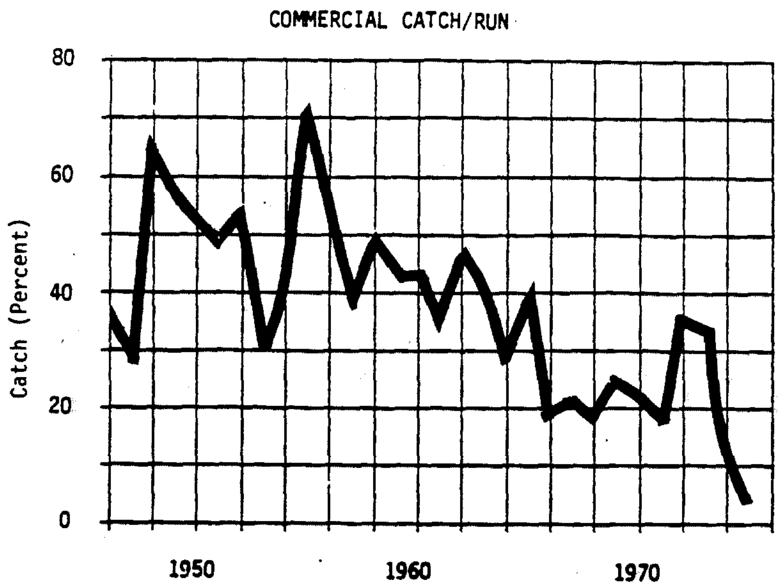

Figure 10: Percentage of the run of spring chinook caught by the commercial fishery in the mainstem Columbia River (Chaney and Perry 1976).

Declines in the lower mainstem Columbia River commercial catches of summer chinook, sockeye, and winter and summer steelhead also are evident, as indicated in Figures 11 and 12. Summer chinook historically have made a significant contribution to the Columbia River harvest. Commercial fisheries harvested nearly 90 percent of the summer runs in the late 1930s and early 1940s (USFWS 1981). From 1945 to 1963, the average annual harvest of all commercial fisheries decreased to 42 percent of the summer run. The percentage of the fall chinook run harvested by the commercial fisheries in the lower mainstem Columbia River declined from a high of 84 percent in 1941 to a low of 35 percent in 1959 (Fish Commission of Oregon and WDF 1972).

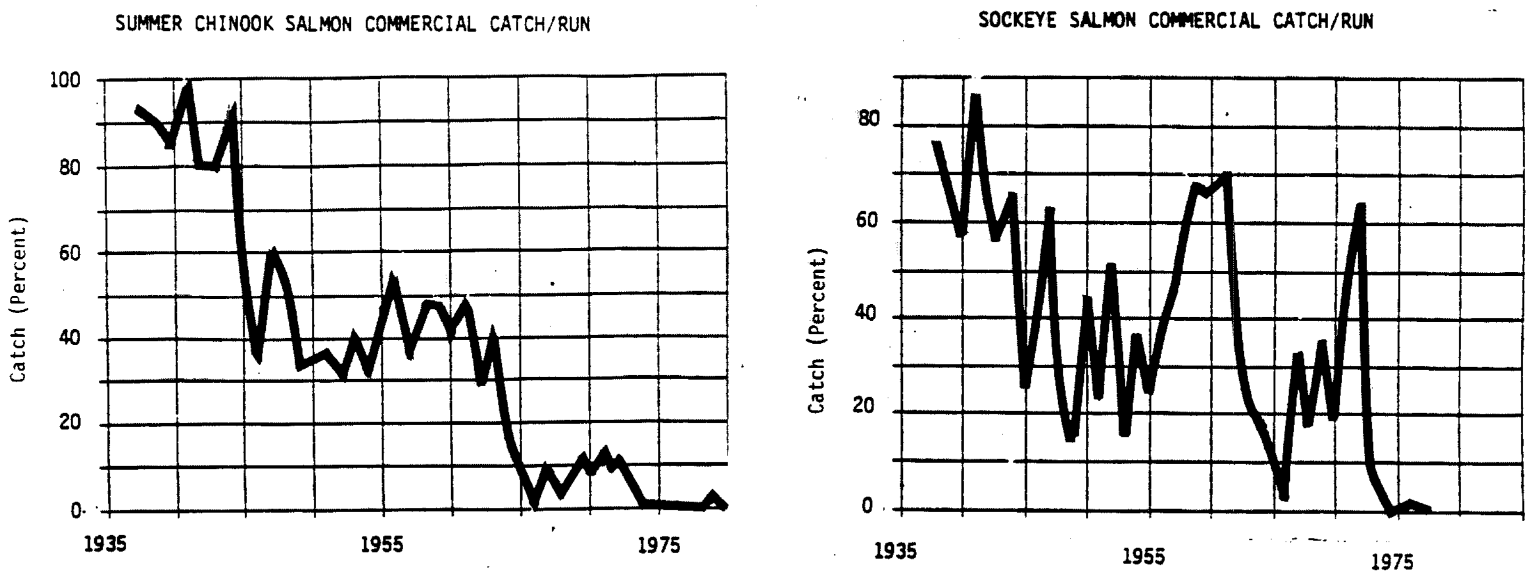

Figure 11. Percentage of the run of summer chinook and sockeye salmon caught by the commercial fishery in the lower mainstem Columbia River (Mullan 1984; USFWS 1981).

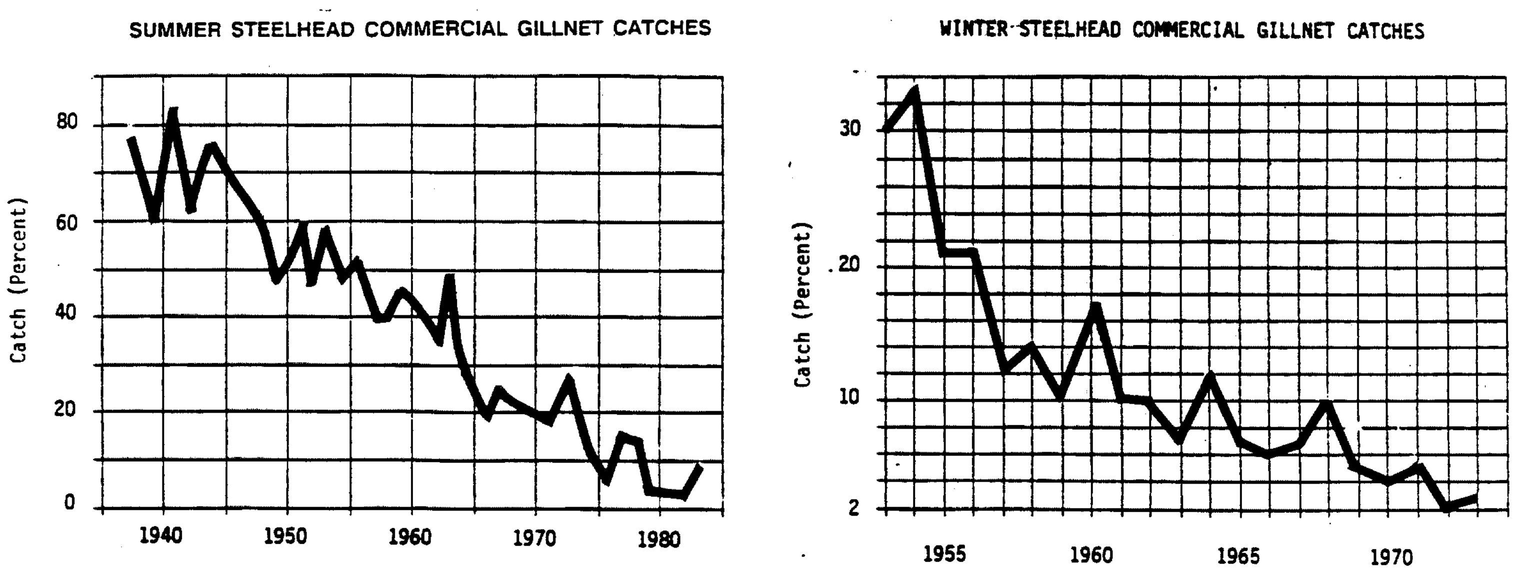

Figure 12. Percentage of the run of summer and winter steelhead caught by the commercial fishery in the lower mainstem Columbia River (Chaney and Perry 1976; ODFW 1985a).

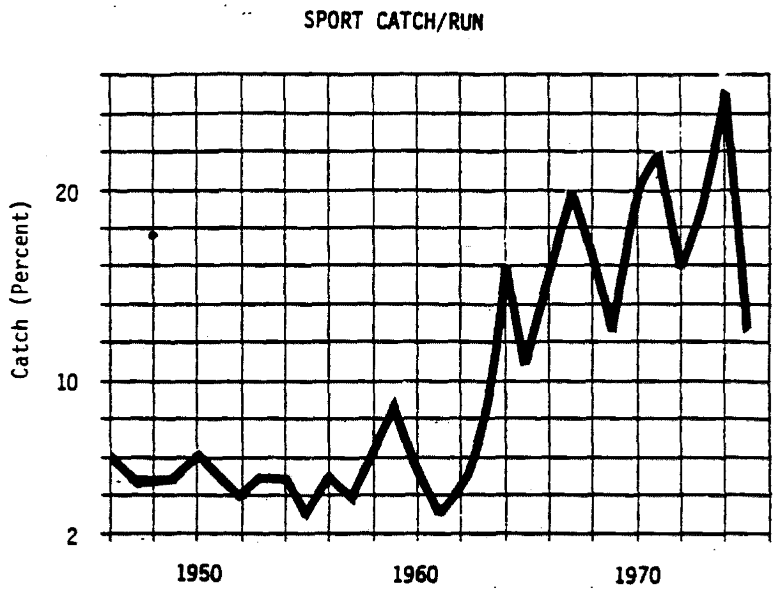

Figure 13. Percentage of the run of spring chinook caught by the commercial and sport fisheries in the mainstem Columbia River (Chaney and Perry 1976).

Inriver harvest rates generally were high for sockeye salmon before 1938 (Mullan 1984). In 1934, about 98 percent of the run was harvested. Since 1938, commercial catches of sockeye salmon have declined. Virtually none were harvested from 1977 to 1982 (Mullan 1984). In 1983, about 1,800 sockeye salmon were harvested commercially above Bonneville Dam (ODFW 1985a). In 1984 and 1985, the tribal catch figures increased to 22,500 and 46,800. A non-tribal sport fishery for sockeye was initiated in 1984 that caught 9,100 fish. In 1985, 29,600 fish were caught in the non-tribal fishery (CRITFC, personal communication).

The percentage of the spring chinook run harvested inriver by commercial and sport fisheries on the mainstem Columbia River for the period 1946 to 1975 is depicted in Figure 13. Inriver sport catch increased from 1961 to 1974. Since 1975, inriver sport catch has declined.

From 1963 through 1983, the sport catch of steelhead trout in the mainstem lower Columbia River has declined (Figure 14).

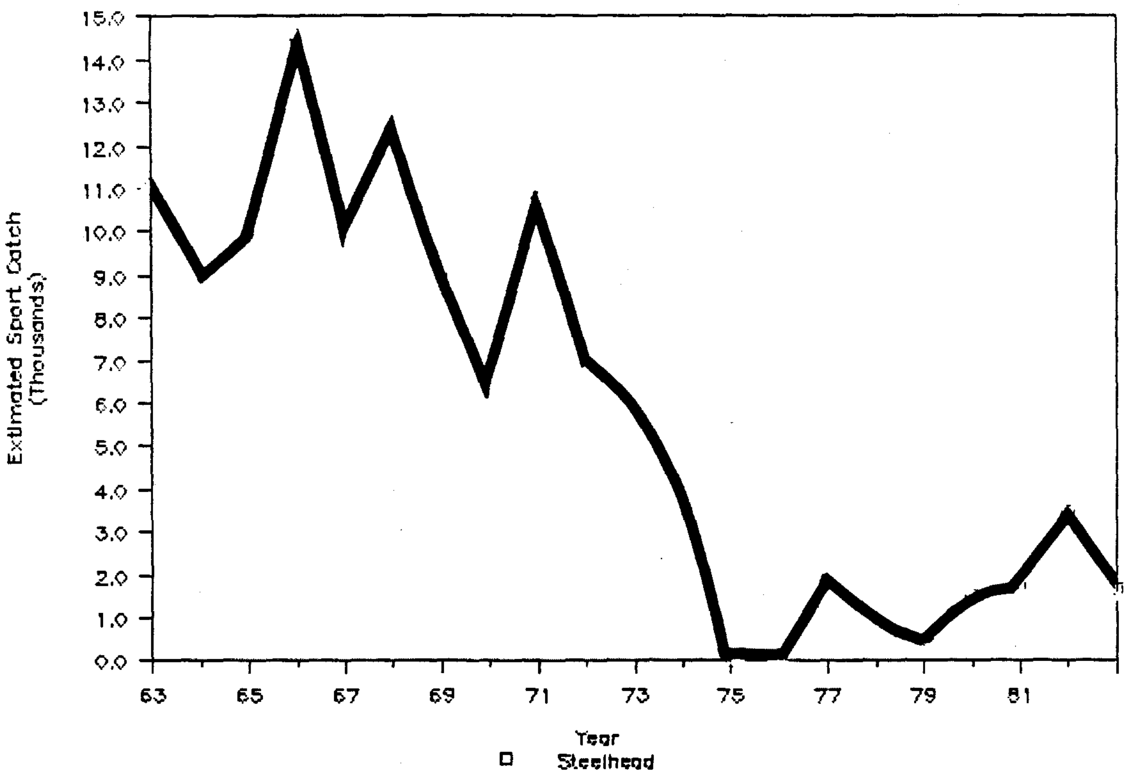

Figure 14. Lower Columbia River steelhead sport catch (ODFW 1985c).

5.2.3 Fisheries in Six Areas of the Columbia River Basin

5.2.3.1 Columbia River Below Bonneville Dam

Sport chatch records for spring chinook in tributaries below Bonneville Dam show an increasing trend in recent times. Spring chinook catches in the Willamette Basin have generally increased since 1946 (Appendix A, Figures A-109). Catches in the Cowlitz, Kalama, and Lewis rivers show an increasing trend since 1970 (Appendix A, Figures A-110, A-111, A-112).

Fall chinook sport catches in the Willamette and Sandy basins showed no definite trends in the 1970s (Appendix A, Figures A-113, A-114).

Coho sport catch in the Clackamas Basin increased in the late 1970s (Appendix A, Figure A-115). Coho catch in the Oregon tributaries below Bonneville Dam show no definite trends (Appendix A, Figure A-116).

Winter steelhead sport catch records are available since the early 1970s for tributaries below Bonneville Dam. Steelhead catch shows no definite trend in the Sandy Basin (Appendix A, Figure A-117), the Oregon tributaries below Bonneville Dam (Appendix A, Figure A-118), and the Kalama Basin (Appendix A, Figure A-119). Catch in the Cowlitz increased in the late 1970s (Appendix A, Figure A-120). Steelhead catch in the North Fork Lewis has increased in the 1980s (Appendix A, Figure A-121). Note that data was not available for the Lewis in 1980 and 1981 because of the eruption of Mt. St. Helens.

5.2.3.2 Columbia River Between Bonneville Dam and Its Confluence with the Snake River

Chinook sport catch records for tributaries in this area of the Columbia Basin have remained relatively stable or declined. Chinook catches in the Hood, Deschutes, John Day, Umatilla/Walla Walla, Wind and Klicktat basins illustrate these trends (Appendix A, Figures A-122, A-123, A-124, A-125, A-126, A-127, A-128). Note that with the exception of the Deschutes, sport catches have been small. Also, the John Day River has been closed to salmon fishing since 1977 due to small run sizes.

Coho salmon sport fishing has occurred in the Hood River (Appendix A, Figure A-129). No trends are apparent for coho catches in this basin in the 1970s.

Steelhead sport catch during the twenty year period from 1963 to 1983 display varying patterns. The Hood River catch has generally increased since the early 1960s (Appendix A, Figure A-122). Catches in the Deschutes, John Day, and Umatilla/Walla Walla basins have generally declined (Appendix A, Figures A-123, A-124, A-125).

5.2.3.3 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

Early catch records of salmon in this area are fragmentary. Prior to development, approximately 160,000 fish were caught annually in the Yakima River system by about 4,000 Yakima, Klickitat, and Priest Rapids Indians (Robison 1957).

The Methow, Wenatchee, Okanogan and Yakima rivers also supported large fisheries. Fish landing statistics for Indian fishermen in the middle Columbia River area give a partial indication of harvest levels from 1947 to 1974 (Figure 15). From the 1950s to early 1970s, annual Indian catches have declined in the Okanogan River for sockeye salmon and in the Yakima River for chinook salmon.

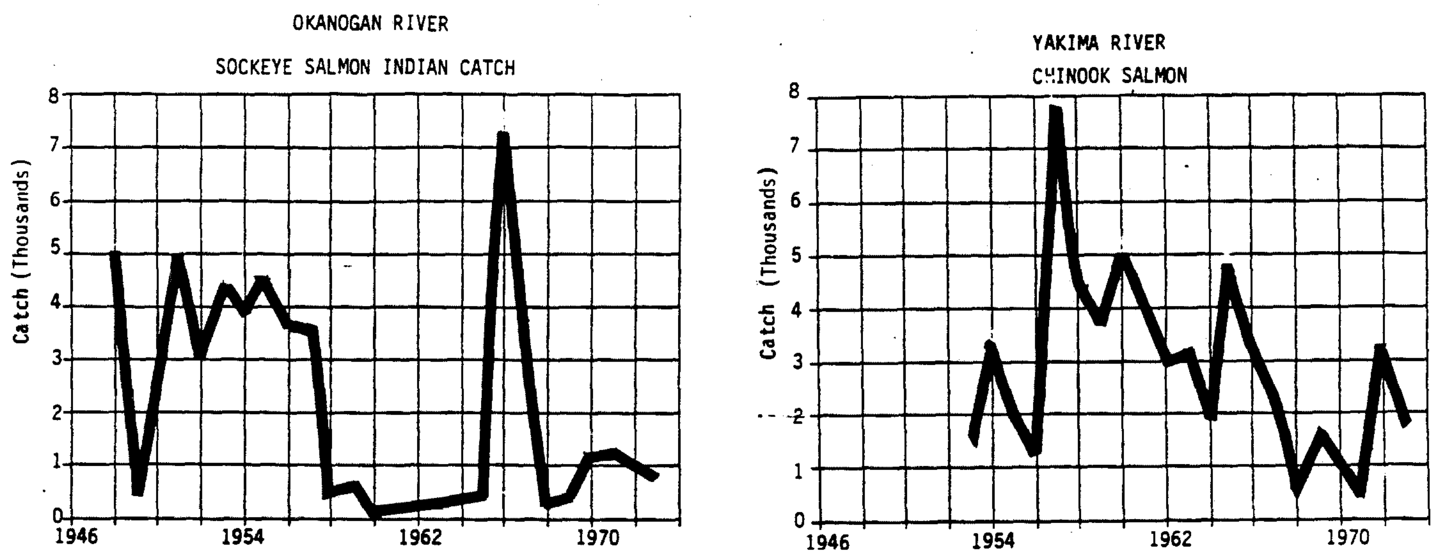

Figure 15. Indian catches of sockeye salmon in the Okanogan River and chinook salmon in the Yakima River (Beiningen 1976b).

The middle Columbia River and its tributaries support important recreational fisheries. Over 1,000 salmon have been taken in the Wenatchee drainage in recent years, targeting on hatchery spring chinook (Appendix A, Figure A-130). Steelhead catches have also been high in some areas, particularly in the Methow and Columbia River above Wells Dam.

Except for Wenatchee River spring chinook, spring and summer chinook and steelhead sport catch information is not available for the Wenatchee, Entiat and Methow rivers (ODFW 1985c).

5.2.3.4 Columbia River Above Chief Joseph Dam

Catch records for this area are limited to Indian catches before Grand Coulee Dam blocked anadromous fish migration in 1939. Little Falls, Kettle Falls, and the Sanpoil area were primary Indian fishing sites in the upper Columbia River. A major Indian basket and spear fishery was located at Kettle Falls. This fishery was used heavily by several upriver tribes.

Likewise, a major fishery was located on the Spokane River at Little Falls until Little Falls Dam was built in 1911. Both of these fisheries were equivalent in numbers of people and, perhaps, numbers of fish taken at The Dalles/Celilio Falls (Scholz et al. 1985).

On the Spokane River at Little Falls missionaries saw 400-800 salmon a day taken during the summer fishing season in the years 1839 to 1848 except for one year (1843) when the run failed to materialize (Drury 1963, 1976). John Work (1830) reported that 700 to 800 salmon per day were taken at Little Falls. L. P. Beach, a cadastral surveyor who surveyed the Spokane River in 1862 reported that the Indians at Little Falls put up at least 250 tons of dried fish during the salmon season (Scholz et al. 1985). As late as 1909 the Indians gathered at Little Falls and caught many salmon (Schotz et al 1985).

Pete Lemery of the Colville Confederated Tribes reported in 1938 that Indians caught 1,353 salmon at Kettle Falls in 1929 and 1,500 in 1931. Earlier estimates of catch at Kettle Falls between the 1840s and the early 1900s range from 900-2,000 daily and hundreds of thousands annually (Scholz et al. 1985). In 1932, when Rock Island Dam was completed, Indians caught 400 salmon. The catch dropped to 263 in 1933 followed by a catch of 139 in 1934.

On the Little Spokane River, Indians reportedly caught about 2,000 salmon in 1883 (Bryant and Parkhurst 1950). David Douglas noted in 1825 that 1,500 to 2,000 salmon a day were speared by Indians. In 1882, 20,000 salmon were seen drying in Indian lodges on the Little Spokane River (Gilbert and Evermann 1894). In 1883, 2,000 salmon were caught on the Little Spokane (Scholz 1985). Steelhead were also taken on this river. The Spokane Falls site also produced many thousands of salmon. Charles Cherapkin, a Coeur d'Alene tribal member, in a letter to President Roosevelt in 1936, estimated that in the period circa 1882, 150,000 salmon were harvested annually by Indians along the length of the Spokane River.

No commercial fishing has occurred in this area. No information was found to indicate whether a sport fishery ever occurred in this area for salmon and steelhead.

5.2.3.5 Snake River Below Hells Canyon Dam

A commercial catch of 2,600 pounds of sockeye salmon is reported from Alturas Lake in 1881 (Ortmann 1970).

The Snake River and its tributary the Salmon River once supported large Indian fisheries (see Chapter 3). For Indians in this area, ceremonial and subsistence catches of chinook have been affected by recent small escapement (USFWS 1981).

Spring and summer chinook once supported a large sport fishery in Idaho, primarily in the Salmon River drainage (USFWS 1981). However, declines in abudance led to a closure of the Snake River harvest in 1965. The decline in abundance and harvest of the Snake River drainage spring chinook stocks is reflected in a shift in location of the harvest. Prior to 1969, fish were harvested from wild stocks throughout the mainstem Salmon River and its major tributaries. Since 1969, fish from hatcheries on the Little Salmon River and in the Clearwater River drainage have become an increasingly important part of the harvest (USFWS 1981).

Spring chinook sport catch information for the Middle Fork and mainstem Salmon rivers is displayed in Figures A-131 and A-132 respectively (see Appendix A).

Idaho anglers harvested an average of 23,000 chinook salmon annually before construction of Ice Harbor Dam on the Snake River in 1961 (Figure 16). Between 1961 and 1969, sport harvest averaged 10,000 chinook annually. The chinook fishing season was closed in Idaho from 1979 to 1984 because of low escapement (Pollard 1985a). The Snake River drainage in Idaho was closed to harvest of summer chinook from 1965 until present and was closed for spring chinook fishing in 1965, 1975 and 1976. The spring chinook season in 1985 was open only on the Little Salmon River. Preliminary estimates indicate a sport catch of 2,000 salmon and an Indian harvest of 4,000 salmon (Richards 1985).

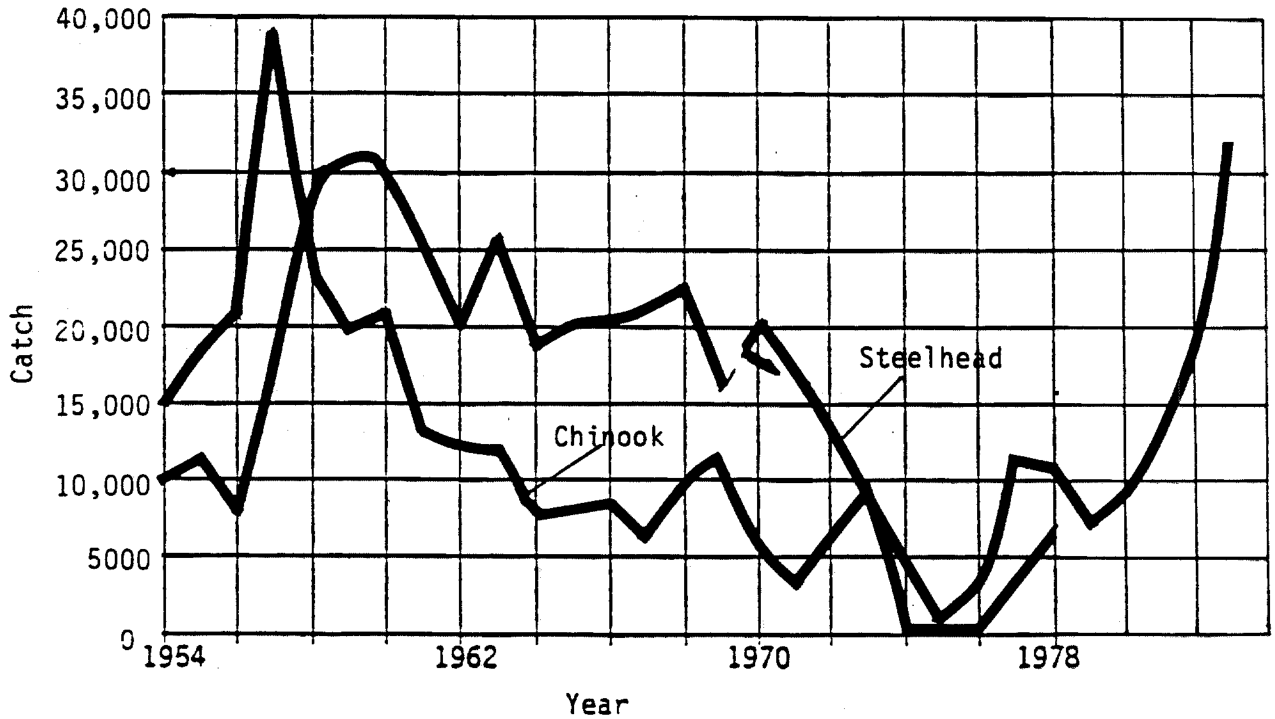

Figure 16. Idaho sport harvest estimates of chinook salmon and steelhead (Pollard 1985a). (Discontinuous curves reflect season closures.)

Sport harvest of spring chinook has declined in other tributaries of the Snake River, such as the Grande Ronde and Imnaha rivers, from the late 1950s to late 1970s (Appendix A, Figures A-133, A-134). The Imnaha River drainage has been closed to salmon and steelhead sport fishing since 1974 (James 1984). Figure A-134 (Appendix A) displays the results of a brief lifting of the Imnaha closure in 1977.

Washington Department of Game annual angler catch estimates starting in 1947 indicate that the sport catch of steelhead in the Tucannon River ranged from less than 100 to over 900 adults until the fishery was closed in 1974 (Appendix A, Figure A-135).

The summer steelhead race is the largest of the Snake River anadromous fish runs. Overall, the steelhead sport catch declined from 1961 to the late 1970s. However, the estimated harvest of steelhead in 1983 totaled 32,262, the highest catch since steelhead harvest estimates were begun in 1954 (Pollard 1985a). Good fishing conditions and increased hatchery production, along with improved survival of juveniles, have contributed to the recent improvement in Idaho (Pollard 1985a). Steelhead sport catches for the Clearwater and Imnaha basins are displayed in Figures A-136 and A-137 respectively (Appendix A).

5.2.3.6 Snake River Above Hells Canyon Dam

Commercial fishing was carried on in the vicinity of Glenns Ferry and at scattered intervals downstream from the mouth of the Boise River to Huntington. The fishermen commonly used seines about 300 feet long, that were pulled over the fishing area with a rowboat on one end and a horse on the the shore end (Ortmann 1970).

Evermann (1896) reported a commercial catch of 4,207 chinook salmon on the Snake River between Huntington and Auger falls, September to November 1894.

E. E. Sherman, fishing below Upper Salmon Falls in 1893, reported that he caught about seven tons of salmon that year (probably a combination of summer and fall chinook). In 1894, Sherman reported that he took about six tons (Ortmann 1970).

Liberty Millet, also fishing below Upper Salmon Falls, reported his 1892 season's catch was between seven and eight tons and that he caught as many as 200 fish in at a single haul. (Ortmann 1970).

Nine fishermen working the Snake River between Huntington and Weiser in September and October 1894 reported catching 2,985 chinook salmon and 3,966 steelhead trout (Ortmann 1970).

William O'Brien, Weiser, Idaho, reported his 1888 and 1894 catches of steelhead were respectively 2,250 and 1,000 fish (Ortmann 1970).

Sockeye populations in Payette Lake were once large enough to support a commercial fishery. Between 1870 and 1880 commercial sockeye catches were estimated to range from 30,000 to 75,000 pounds per year. In 1888, the catch at Payette Lake dropped considerably with only two catches of 800 and 600 pounds each reported.

5.2.4 Regulation of Fishing

5.2.4.1 Columbia Basin Fisheries

The increasing exploitation of salmon and steelhead in the Columbia River during the late 1880s required regulation of the commercial fishery in the lower Columbia River. During this period, every conceivable type of fishing gear was used year around without control. Regulation of commercial gear began in 1866. Table 17 summarizes when certain types of fishing gear were eliminated from the Columbia River.

Table 17 - Years that certain fishing appliances were prohibited from the Columbia River.

Gear	Year Oregon	Year Washington
Gaffs, spears, foul hoods	1901	unknown
Purse seines	1917	1917
Whip seines	1923	1923
Haul (drag) seines	1949	1935
Set nets	1949	1935
Traps	1949	1935
Fish wheels	1927	1935

Source: Wendler (1961).

Seasonal regulations governing commercial fishing began in 1877. Minimal efforts were made to enforce these early regulations. From 1877 to 1908, fishing regulations enacted independently by Oregon and Washington complicated enforcement efforts. One of the most significant regulatory actions was the ratification by Congress in 1918 of the Columbia River Compact between the states of Oregon and Washington (see Act of April 8, 1918, Pub. L. No. 65-123,40 Stat. 515 (1918); Wash. Rev. Code Ann. § 75.40.010, Ore. Rev. Stat. § 507.010). The compact provided for regulation of the commercial fisheries in concurrent waters of the Columbia River by mutual consent, with each state having one vote. The tribes and Idaho are not members of the compact and therefore have no vote in determining regulations for this portion of the river. Gear and season regulations governing commercial fishing from 1866 to 1963 are summarized in Tables 18 and 19 for Oregon and Washington.

Table 18 - Commercial gear regulations on the Columbia River, Oregon and Washington[1] --1866 to 1961.[2]

Year	Oregon	Washington	Regulation
1866		X	Unlawful to build a fish trap that would reach more than two-thirds of the way across or wholly prevent the passage of fish up and down the Walla Walla River
1871		X	Unlawful to build or place a fish trap, weir, seine, or net that would reach more than two-thirds of the way across freshwater streams or creeks, or that would wholly prevent the passage of fish either up or down. The above gear was not to be used in lakes.
1878	X		First year of gear regulation. Specified minimum mesh sizes and spacing between slats on traps. Also required traps and weirs to have an opening to permit the free passage of fish during the weekly closed period.
1879		X	Passed legislation similar to the 1878 legislation of Oregon.
1890		X	Fixed gear could not extend more than halfway across any channel or slough.
1891	X		Fixed gear could not extend more than one-third of the way across a channel or slough.
1893		X	Specified the maximum length of fixed gear and the minimum distances between such gear.
1897		X	Minimum size of mesh of fixed gear specified.
1898	X		A fish wheel could not be prepared to take fish during a closed season.

1 All commercial fishing for salmon and steelhead in the Columbia River Basin occurs in the mainstem below McNary Dam. This area is outside the state boundaries of Idaho.

2 Source: Wendler (1966).

Table 18 (cont)

Year	Oregon	Washington	Regulation
1899	X	X	Chinese sturgeon line prohibited.
1901	X		Gaffs, spears, and foul-hooks prohibited.
1907	X		Purse seines prohibited
1909	X		Purse seines permitted in Columbia River if licensed.
1913	X		Maximum length of fixed gear and minimum passageways between such gear specified.
1915	X	X	Length of appliances could not be more than one-third width of the river. Gill net minimum mesh of 5 inches. Further regulation of fixed gear (Oregon only). Also provided for licenses for trolling in the Columbia River and for purse seines (Oregon only).
1917		X	Purse seines prohibited in the Columbia River. Regulations provided for a v-shaped opening in trap leads, to be opened during closed periods. Hook-and-line fishing in the Columbia licensed.
1917	X		Purse seine fishing prohibited in Columbia River. Commercial trolling license required.
1919	X		Illegal to have purse seine on the Columbia River even if not fishing.
1921		X	Saltwater hook-and-line fishing licensed (possibly meant troll).
1923	X	X	Whip seines prohibited in the Columbia River.
1927	X		Fish wheels prohibited in Oregon waters. Unlawful to use traps or seines above Cascade Locks in Oregon waters. Gill net maximum length set at 250 fathoms.
1935	X		Seines again permitted east of Cascade Locks.
1937	X		Maximum length for gill nets abolished in Oregon.
1949	X		Drag seines, traps, and all fixed gear prohibited; this act not in effect until 9/14/50 due to an injunction which allowed fixed gear to operate until that date.

Table 18 (cont)

Year	Oregon	Washington	Regulation
1955	X	X	Mesh size restriction went into effect from June 20 to July 15 below Bonneville Dam from July 14 to July 30 above the dam. Unlawful to use mesh size less than 5 1/4 inches during above period.
1956	X	X	Same as above from June 20 to June 29 below Bonneville Dam and from July 4 to July 17 above the dam.
1957-1961	X	X	Illegal to fish above Bonneville Dam for commercial purposes. Maximum length of gill net set at 250 fathoms (1,500 feet).
1962	X	X	Mesh restriction in effect from June 23 to July 15 prohibiting use of mesh less than 5 inches.
1963	X	X	Mesh restriction in effect from June 15 to July 15 prohibiting use of mesh less than 5 inches.

Table 19 - Seasonal regulations governing commercial fishing on the Columbia River by year, 1877 to 1942.1/

Year	Oregon	Washington	Regulation
1877		X	March, April, August, and September closed to salmon fishing. May, June, and July had a weekly closed period from 6 p.m. Saturday to 6 p.m. Sunday.
1878	X		Same as above except that April was open to fishing subject to weekly closed period.
1879		X	1977 Regulation changed to agree with 1878 Oregon regulation.
1880	X		Weekly closed period from sunset Saturday to sunset the Sunday following at any season of the year.
1881		X	September open to fishing. No weekly closed period provided.
1890		X	Closed seasons from March 1 to April 10 and from August 10 to September 10.
1891	X		Closed seasons made to conform with those of Washington. Weekly closed period from 6 p.m. Saturday to 6 p.m. the Sunday following.
1895		X	Weekly closed period done away with.
1898	X		Closed season from 12 m. February 15 to 12 m. April 15, and from 12 m. August 10 to 12 m. September 10.
1899	X		Spring season closed from 12 m. March 1 to 12 m. April 15.
1899		X	Closed season from 12 m. March 1 to 12 m. April 15, and from 12 m. August 10 to 12 m. September 10. No mention of weekly closed periods.

1/ Source: Wendler (1961).

Table 19 (cont)

Year	Oregon	Washington	Regulation
1901	X		Closed season from 6 a.m. March 1 to 6 a.m April 15, and from 6 a.m. August 15 to 6 a.m. September 10. Weekly closed period from 6 p.m. Saturday to 6 p.m. the Sunday following from April 15 to August 15.
1901		X	Fall closed season shortened 5 days by moving starting time back to 12 m. August 15.
1903	X		Weekly closed periods removed.
1905		X	Spring closed season began 12 m. March 15, and the fall closed season 12 m. August 25. The fishing season was thus lengthened 25 days.
1908	X		Initiated petitions were passed at a general election which radically changed the season and the legal gear, but these regulations were repealed before they had been in effect long.
1909	X	X	Fishing season began on January 1 of the calendar year, closed on March 1, was reopened on May 1 and allowed to progress to August 25. The season reopened on September 10. Closed periods occurred during the entire months of March and April, and from August 25 to September 10. All seasons began at 12 noon and closed at 12 noon.
1937	X	X	Spring season opened on April 26 thus allowing an additional 5 days fishing time.
1938	X	X	Spring season opened May 1.
1941	X	X	Spring season opened April 29 and closed August 26.
1942	X	X	Spring season opened May 1 and closed August 26.

Go To Next Part

Go To Next Part

Commercial fishing regulations on the Columbia River continue to be regulated under the compact. Idaho and the basin Indian tribes do not have a vote on the compact (Coon 1985).

Seasonal and weekly periods closed to fishing have continually increased, resulting in a decline in the number of days open to fishing each year. The Columbia River commercial fishing seasons below Bonneville Dam have been reduced from over eight months per year in the early 1940s to about 82 days per year in the early 1970s to a low of 14 days in 1980 (Figure 17). The number of gill net licenses issued each year also declined from 1928 to 1969, but has increased to over 1,000 licenses since 1971 (Figure 18).

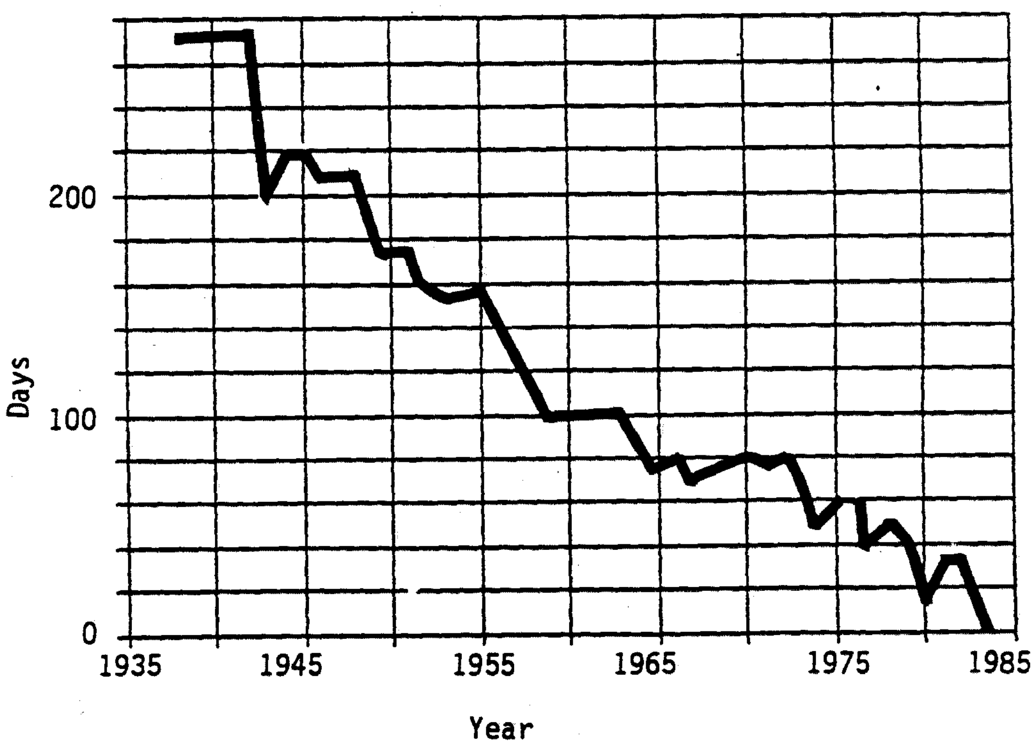

Figure 17. Days open to commercial fishing in the lower Columbia River area (Johnson, Chapman and Schoning 1948).

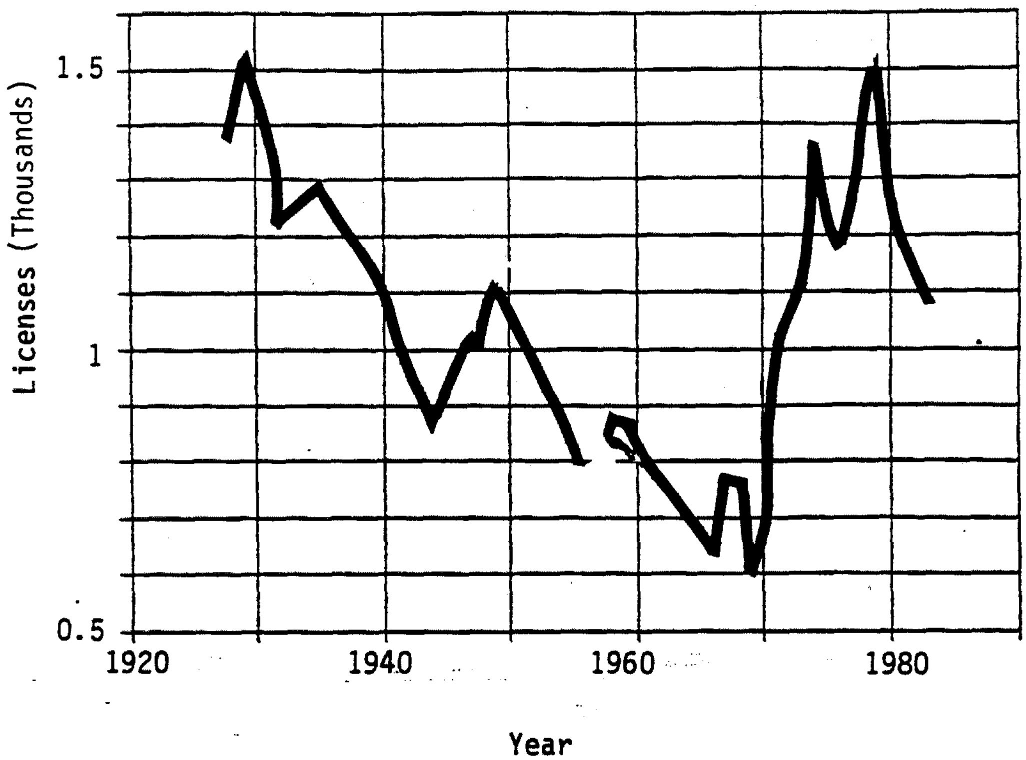

Figure 18. Gill net licenses issued annually in lower Columbia River area (ODFW 1985a; Fish Commission of Oregon and Washington Department of Fisheries 1972).

Fishing regulations in Idaho began in 1939 (Richards 1985). The most significant regulation, which was implemented in 1982, requires (in some waters) or encourages the release of wild steelhead as determined by dorsal fin height (Richards 1985; Pollard 1985a). This regulation is intended to increase reduced runs of wild steelhead in Idaho. Catch-and-release fishing for steelhead also is regulated in some Idaho streams. The chinook salmon season in Idaho was closed from 1979 to 1984 because of low escapement. In 1985, chinook sport fishing was allowed in the Little Salmon River and in the mainstem Snake River (Richards 1985).

5.2.4.2 Ocean Fisheries

Prior to 1948, there were few restrictions on the ocean fisheries (Phinney 1976). The state commercial fisheries agencies of Washington, Oregon, and California met in 1945 to discuss formation of the Pacific Marine Fisheries Commission (PMFC). A tri-state compact was authorized in 1947 by Congress and respective state legislative sessions (see Pacific Marine

Fisheries Compact, Pub. L. No. 80-232, 61 Stat. 419 (1947), as amended by Act of October 9, 1962, Pub. L. No. 87-766, 76 Stat. 763 (1962)). The purposes of the PMFC were to promote better use of marine fisheries and to develop a joint program of protection and prevention of physical waste in these fisheries in all areas of the Pacific Ocean and adjacent waters over which the compacting states jointly or separately acquired jurisdiction (Phinney 1976). Idaho was not a part of this compact.

The PMFC subsequently recommended salmon troll regulations that were adopted by Oregon, Washington, and Alaska. These included a minimum 26-inch length of chinook salmon, a March 15 to November 1 open season for chinook salmon, and a June 15 to November 1 open season for coho salmon. In 1975, the salmon troll regulations included a minimum length of 26-1/2 inches on chinook salmon, an April 15 through October 31 season for chinook salmon, and a June 15 through October 31 season for coho salmon (Poon and Garcia 1982).

In the mid-1970s, the inriver fisheries declined concurrently with an fluctuating ocean fisheries (Table 20). Partially as a result, the Fisheries Conservation and Management Act (FCMA), or Magnuson Act, was enacted in 1976 to provide federal jurisdiction for management of all fisheries within 200 miles of the U.S. coastline, except for the area within zero to three miles where management authority resides within each state (see Pub. L. No. 94-265, 90 Stat. 331 (codified at 16 U.S.C. 1801-1882)). This exception is subject to federal preemption by the Secretary of Commerce.

The Pacific Fishery Management Council (PFMC) and the North Pacific Fishery Management Council (NPFMC) were formed in 1977 as a result of the Magnuson Act. The councils were intended to provide a management framework for producing the optimum yield of commercial and sport fisheries on the Pacific Coast. The PFMC manages the fisheries off the coast of Washington, Oregon, and California, and the NPFMC manages the area off Alaska. Funding for the councils is provided annually as part of the U.S. Department of Commerce budget (Coon 1985).

The U.S.-Canada Pacific Salmon Treaty was signed into law in 1985. Under this treaty, both countries will be committed to preventing overfishing and to providing optimum coastwide management. The treaty reduces Columbia River Basin chinook salmon harvests off southeastern Alaska and British Columbia to

Table 20 - Comparison of Columbia River commercial landings with commercial ocean troll landings 1971-1983.[1]

Year	Chinook Salmon		
		Ocean	
	Columbia River	Oregon	Washington
1971-1975 average	324	209	262
1976	288	184	335
1977	256	340	217
1978	189	191	130
1979	171	242	123
1980	150	205	113
1981	95	158	91
1982	155	222	122
1983	55	76	49

Year	Coho Salmon		
		Ocean	
	Columbia River	Oregon	Washington
1971-1975 average	209	981	850
1976	172	1,827	1,347
1977	40	446	657
1978	136	612	547
1979	132	703	630
1980	150	374	342
1981	62	610	351
1982	206	507	239
1983	7	318	23

[1] In thousands of fish.

meet rebuilding goals for the chinook runs. Season structure (e.g., starting dates, planned inseason closures, and possible single species fisheries) is critical to developing realistic expectations of benefits from this treaty (PFMC 1985b).

5.2.5 Summary -- The Current Status of Fishing Impacts on Fish

The current ocean commercial and sport fishery is a mixed-stock fishery that harvests both hatchery-reared and natural stocks from a variety of different areas. The mixed-stock ocean harvest of Columbia River Basin salmon occurs off the coasts of Alaska, British Columbia, Washington, Oregon, and California. Ocean harvest in U.S. waters is regulated by Pacific Coast states, the Pacific Fishery Management Council, the North Pacific Fishery Management Council, and the Secretary of Commerce. In recent years there have been significant reductions in ocean harvest in an effort to reduce impacts on weak stocks. In addition, the U.S.-Canada Pacific Salmon Treaty contains provisions for limiting catches in areas off Canada and Alaska where Columbia River chinook have historically been harvested.

Inriver fishing impacts on salmon and steelhead stocks in the Columbia River Basin also have been curtailed in recent years through more restrictive gear and season regulations. Inriver commercial gill net fishing has been strictly regulated since 1982 to increase spawning escapement (Edwards 1985).

5.3 HYDROPOWER DEVELOPMENT AND OPERATIONS

5.3.1 The Development of Columbia Basin Hydropower

Hydropower development in the Columbia River Basin began in the late 1800s when dams were constructed on larger mainstem tributary systems such as the Willamette and Spokane rivers (Collins 1976). Development proceeded at a rather slow pace during the early 1900s. A common characteristic of most of these early hydropower dams was their relatively small storage capacity. The first dams constructed exclusively for hydropower were in the lower and upper Columbia River areas.

The T. W. Sullivan Dam built in 1888 at Willamette Falls on the Willamette River was the first hydroelectric facility in the Columbia River Basin. This was followed by the Monroe Street (1896) and Lower Bonnington (1898) hydroelectric dams, constructed in the Upper Columbia area on the

Spokane and Kootenay rivers by Washington Water Power Company and West Kootenay Power and Light, respectively. The Washington Water Power Company constructed four additional hydroelectric facilities on the Spokane River from 1906 to 1915.

The first hydropower dam in the Snake River Basin was built by the City of Idaho Falls at Idaho Falls-Lower in 1904. The first multipurpose projects including hydropower were constructed in the Snake River Basin by the federal government at Minidoka Dam on the Snake River in 1906, and at the Boise Diversion Dam on the Boise River in 1908. The C. P. National Company built the first private hydropower project in the Snake River Basin in 1905 on Rock Creek in the Powder River Basin, followed closely by Idaho Power Company's Shoshone Falls Dam on the Snake River in 1907.

In 1905, the Okanogan Public Utility District constructed Enloe Dam on the Similkameen River between the Snake River and Chief Joseph Dam. This was followed closely by the construction of the Naches Dam on the Naches River in 1906, and Dryden and Tumwater dams built by Valley Power Company and the Great Northern Railway on the Wenatchee River in 1907 and 1909, respectively. Dryden and Tumwater dams were acquired in the late 1940s and have been operated by Chelan County Public Utility District since that time.

After the Sullivan plant, hydropower development below Bonneville Dam did not resume until Portland General Electric Company built River Mill and Marmot dams on the Clackamas and Sandy rivers in 1911 and 1912, respectively. The next significant period of hydroelectric development in this area followed in 1929 with the construction of Bull Run Dam No. 1 on the Bull Run River by the City of Portland and then Leaburg Dam on the McKenzie River in 1930 by Eugene Water and Electric Board. Most hydroelectric development in this area occurred during the 1950s and 1960s, when 162 megawatts and 124 megawatts, respectively, were added to the area's total generating capacity. There has been very little hydroelectric development below Bonneville Dam since 1970.

The first hydroelectric development between Bonneville Dam and the confluence of the Snake River resulted from construction of the Bend and Cline Falls dams on the Deschutes River and Condit Dam on the White Salmon River all in 1913, by Pacific Power and Light Company. Pacific Power and Light Company also constructed the Powerdale Dam on the Hood River in 1923.

The first major period of hydropower development on the mainstem Columbia River commenced in the 1930s with the construction of the Rock Island Dam in 1933 by Puget Sound Power and Light Company (later acquired by Chelan PUD), followed by the completion of the Bonneville Dam by the Corps of Engineers in 1938. Within a 45-year period following these initial developments, 14 mainstem Columbia and 13 mainstem Snake River dams were completed within the natural limits of historical anadromous fish runs (Table 21). Hydropower development in the tributaries of the Columbia River Basin also continually increased since the 1930s with much of the construction occurring in the period from 1950 to 1970.

Overall, 58 dams have been constructed exclusively for hydropower in the Columbia River Basin (Table 22). Of these, 17 are located in the lower Columbia River area below Bonneville Dam. Another 15 dams are in the upper Columbia River area above Chief Joseph Dam, while 16 are located in the upper Snake River area above Hells Canyon Dam. Six dams constructed exclusively for hydropower are in the Clackamas drainage in the lower Columbia River area and in the Kootenay drainage in the upper Columbia River area above Chief Joseph Dam. The mainstem Snake not only has the most dams, but also the most large dams of any river in the entire basin.

In addition to 58 exclusively hydropower dams, there are 78 multiple purpose projects which include hydropower production in the Columbia River Basin. Of these multipurpose dams with hydropower, 19 are found in the lower Columbia River area below Bonneville Dam, 18 in the upper Columbia River area above Chief Joseph Dam and 14 in the Snake River area above Hells Canyon Dam. Multipurpose hydropower dams in the remaining three areas are fairly evenly distributed (Table 22).

The Corps (1984) states that prior to the 1930s most water resource developments in the Pacific Northwest were constructed for single purpose objectives -- mainly power generation, irrigation, flood control, or municipal and industrial water supply. These developments were mainly on coastal basin streams and on tributaries of the Columbia River, usually near large population concentrations or near areas where irrigation was feasible.

Table 21 - Completion dates of Columbia and Snake river dams which affect anadromous fish.

Dam	Year of Initial Service	Normal Maximum Head (feet)	Length of Reservoir (miles)
Columbia River			
Rock Island	1933	54	21
Bonneville	1938	62	46
Grand Coulee	1941	343	151
McNary	1953	75	61
Chief Joseph	1955	177	52
The Dalles	1957	85	24
Priest Rapids	1959	82.5	18
Rocky Reach	1961	93	42
Wanapum	1963	83.5	38
Wells	1967	72	29
John Day	1968	105	76
Keenleyside (Arrow)	1968	69	145
Mica	1973	615	135
Revelstoke	1983	425	80
Snake River			
Shoshone Falls	1907	212	
Swan Falls	1910	24	8
Lower Salmon (Salmon Falls)	1910	60	6
Upper Salmon A	1937	43	
Upper Salmon B	1947	37	
Bliss	1949	70	5
C. J. Strike	1952	88	
Brownlee	1958	272	57
Oxbow	1961	120	12
Ice Harbor	1961	100	32
Hells Canyon	1967	210	22
Lower Monumental	1969	100	29
Little Goose	1970	98	37
Lower Granite	1975	100	5

Source: Oregon Department of Fish and Wildlife (1985a), Corps of Engineers (1984).

Table 22 - Number of hydroelectric dams by major drainages in the Columbia River Basin.

Study Area	Exclusive Hydropower	Multipurpose with Hydropower
Columbia River Below Bonneville Dam		
Clackamas	6	1
Columbia (mainstem)	0	0
Cowlitz	0	3
Lewis	1	3
McKenzie	5	1
Sandy	1	4
Santiam	1	4
Willamette	3	3
Total	17	19
Columbia River Between Bonneville Dam and Snake River Confluence		
Columbia (mainstem)	0	4
Crooked	1	0
Deschutes	4	2
Hood	1	1
White Salmon	0	1
Total	6	8
Columbia River Between Snake River and Chief Joseph Dam		
Columbia (mainstem)	0	5
Chelan	0	1
Naches	2	1
Okanogan	1	0
Wenatchee	1	1
Yakima	0	2
Total	4	10
Columbia River Above Chief Joseph Dam[1]		

Table 22 (cont)

Columbia (mainstem)	0	4
Colville	1	0
Cranberry	1	0
Kootenai (U.S.)	0	1
Kootenay (Canada)	6	1
Pend Oreille	4	7
Spokane	3	5
Total	15	18
Snake River Below Hells Canyon Dam		
Clearwater	0	1
Imnaha	0	3
Snake (mainstem)	0	4
Wallowa	0	1
Total	0	9
Snake River Above Hells Canyon Dam[2]		
Boise	0	3
Henry's Fork	1	0
Malad	2	0
Owyhee	0	1
Payette	0	3
Powder	1	0
Snake (mainstem)	12	7
Total	16	14
TOTAL BASIN	58	78

Source: Corps of Engineers (1975); Bonneville Power Administration (1980); Heitz et al. (1980); and Washington State Department of Ecology (1981); Corps of Engineers (1984); and Bonneville Power Administration (1983).

[1] Includes only major (equal to or greater than 5 megawatts) projects in the upper Columbia River Basin in British Columbia.

[2] Includes only major (equal to or greater than 5 megawatts) projects in the upper Snake River Basin above Shoshone Falls.

In the 1930s, Congress authorized two major multiple-purpose projects -- the Grand Coulee Project in Washington and the Bonneville Project in Oregon and Washington. This signaled the start of intensive development of the Columbia River and its tributaries. Construction of the Bonneville Project was initiated in 1933 with navigation, flood control, and power generation designed as major project purposes. This project was started by the Works Progress Administration and completed by the Corps of Engineers. The Grand Coulee Project in Washington, constructed by the Bureau of Reclamation, was authorized in 1935. The Bonneville Power Administration was created in 1937 to market the energy produced by these and other federal hydroelectric projects in the Columbia River Basin.

Following World War II, the Corps built major projects at McNary, Albeni Falls, Chief Joseph, The Dalles and in the Willamette Basin. The U.S. Bureau of Reclamation constructed projects at Hungry Horse, Anderson Ranch, and Palisades. However, during the middle and late 1950s, federal water resource development was largely curtailed. Construction continued on projects already underway, but design and construction were delayed for new projects.

The "no new starts" policy of the 1950s eventually was rescinded, and the construction of federal projects was resumed. Projects constructed by the Corps include John Day on the mainstem Columbia; Libby Dam on the Kootenai River in Montana; Dworshak on the North Fork of the Clearwater River in Idaho; Ice Harbor, Lower Monumental, Little Goose, and Lower Granite on the Lower Snake River; and additions to the Willamette Basin system of reservoirs. During this same period, the Bureau of Reclamation constructed additional projects in the Snake River Basin, and Bonneville Power Administration expanded its power transmission facilities. During the 1950s, Grant PUD, Chelan PUD, and Douglas PUD requested licenses for more large mid-Columbia River projects. During this period financing arrangements were developed whereby the power output of these projects was marketed to other utilities, as the capability of these large plants far exceeded the loads of the licensees. Under such arrangements construction was started on Priest Rapids in 1956, Rocky Reach in 1957, Wanapum in 1959, and Wells in 1963. All are in the middle Columbia River reach between the Snake River and Grand Coulee Dam (Corps 1984).

Other major hydroelectric projects were constructed by public and private utilities on tributary rivers during the 1950s and 1960s under terms of Federal Power Commission (now the Federal Energy Regulatory Commission) licenses. These included the three middle Snake projects--Brownlee, Oxbow and Hells Canyon dams--constructed by Idaho Power Company; Noxon and Cabinet Gorge Projects on the Clark Fork River constructed by the Washington Water Power Company; Box Canyon Projects on the Pend Oreille River, constructed by Pend Oreille Public Utility District; Boundary Project on the Pend Oreille River, constructed by Seattle City Light; Round Butte and Pelton projects on the Deschutes River, constructed by Portland General Electric Company; Swift and Yale projects on the Lewis River, constructed by Pacific Power and Light Company, Mossyrock and Mayfield projects on the Cowlitz River, constructed by Tacoma City Light; Carmen-Smith Project on the McKenzie River, constructed by Eugene Water and Electric Board; and Timothy Lake and North Fork projects on the Clackamas River, constructed by Portland General Electric Company (Corps 1984).

The Corps (1984) states that three events occurred in 1964 that significantly affected reservoir regulation and the flow regime of the Columbia River. These were ratification of the Columbia River Treaty with Canada, authorization of the Pacific Northwest-Southwest high voltage transmission interconnections, and the Pacific Northwest Coordination Agreement. These actions were closely interdependent, and the sequence for completion of each was tied to the accomplishments expected of each preceding dam.

The mainstem sections of the Columbia and Snake rivers represent the predominant rivers developed for hydropower in the Columbia River Basin. The mainstem Snake River has the most hydropower projects with 21, followed by the mainstem Columbia River, which has 13 projects. The most highly developed tributary drainage is the Pend Oreille River Basin in the Columbia River area above Chief Joseph Dam, which has 11 hydroelectric projects (Table 22 and C-1). The locations of major hydropower (exclusive and multipurpose) and other dams in the basin are shown in Figure 19. Appendix C (Table C-1) contains a listing of all hydropower and non-hydropower dams in the basin.

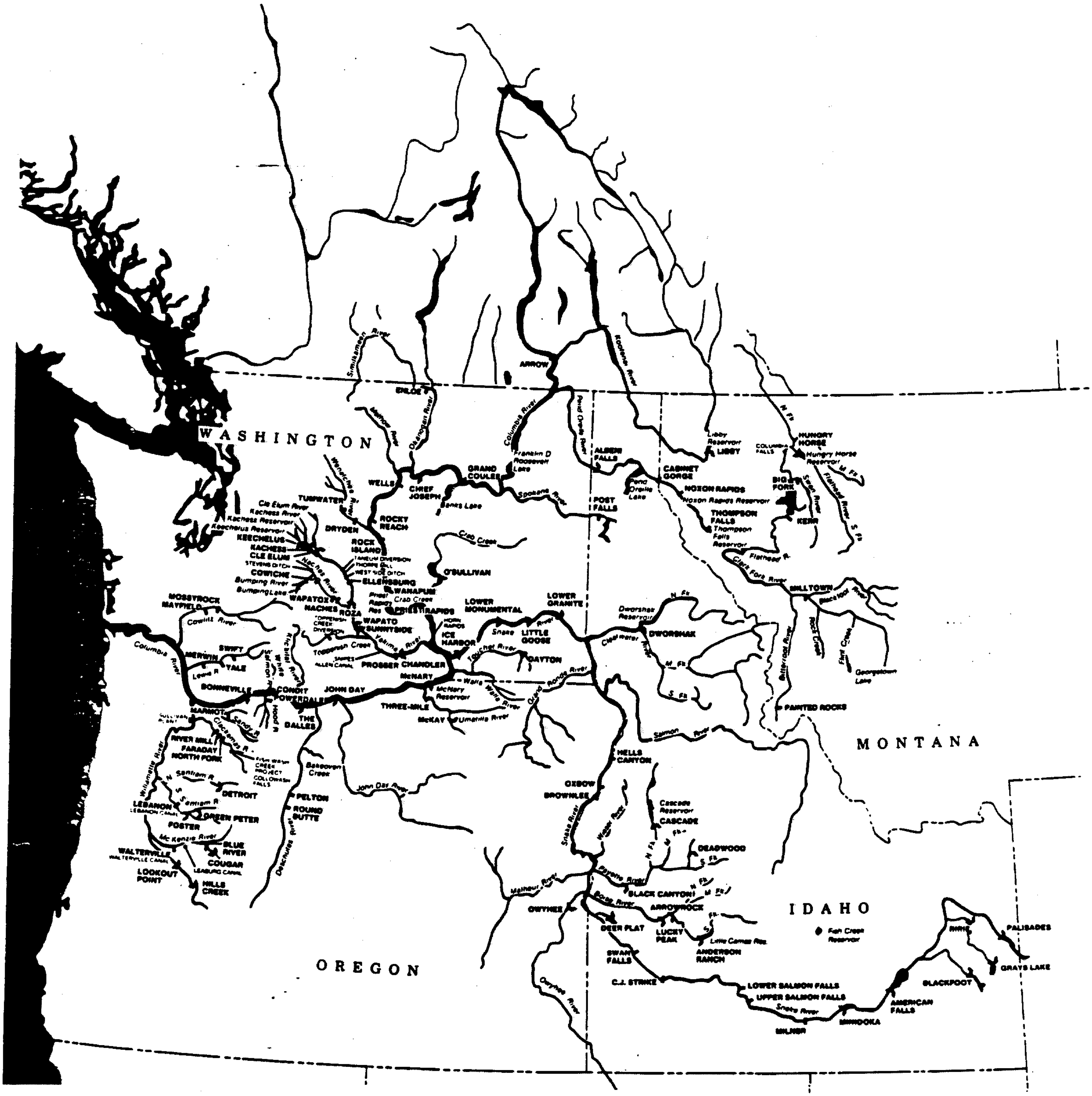

Figure 19. Location of hydropower and other dams in the Columbia River Basin.

The ownership of the two types of hydropower dams (exclusive and multipurpose) in the Columbia River Basin is significantly different (Table 23). Of the 58 dams developed exclusively for hydropower, 41 are privately-owned and operated. City municipalities own nine dams, while public utility groups account for three dams. These private hydropower dams are comprised of both small and large projects, with a combined total generating capacity of only about 1,800 megawatts out of the 3,183-megawatt total capacity for all dams which are operated exclusively for hydropower generation.

In contrast, the federal government plays a major role in developing multipurpose dams with hydropower as one of the purposes. The Bureau of Reclamation and Corps of Engineers operate 33 of the 78 multipurpose dams with a combined total generating capacity of 19,423 megawatts out of the 30,813 megawatt total capacity for all multipurpose dams. Private companies also operate a large number (27) of multipurpose projects (Table 23), but they are considerably smaller projects with a combined total generating capacity of only 2,352 megawatts. Public utility groups own and operate 10 multipurpose dams which also produce hydropower. These generate a total of 4,364 megawatts.

In summary, there are 136 hydroelectric projects of all categories presently operating within the Columbia River Basin, considering all projects greater than or equal to one megawatt within historical limits of anadromous fish runs, plus those projects outside the present limits of anadromous fish runs where the installed generating capacity exceeds five megawatts. Of those projects, 10 are located in British Columbia, Canada. The total reservoir storage capacity in all hydroelectric projects (including pondage in run-of-river projects) is 74.9 million acre-feet. The total installed hydroelectric generation of all of these projects is presently about 34,000 megawatts.

The Corps of Engineers (1984) defines major hydroelectric projects as those having a total storage capacity in excess of 100,000 acre-feet, or an installed power generating capacity greater than 40 megawatts. There are 66 such projects within the Columbia River Basin. Their combined total storage capacity is over 74.2 million acre-feet. Their combined hydropower generating capability is about 33,430 megawatts.

Table 23 - Ownership of hydropower dams in the Columbia River Basin.

Area	Federal/ Provincial	Exclusively Hydropower State	Municipal	PUDs	Private	Total
A Lower Columbia below Bonneville	1	0	5	1	10	17
B Lower Columbia above Bonneville	0	0	0	0	6	6
C Middle Columbia	0	0	0	2	2	4
D Upper Columbia	4	0	1	0	10	16
E Lower Snake	0	0	0	0	0	0
F Upper Snake	0	0	3	0	13	16
Total Columbia Basin	5	0	9	3	41	58

Area	Federal/ Provincial	Multipurpose with Hydropower State	Municipal	PUDs	Private	Total
A Lower Columbia below Bonneville	7	0	5	1	6	19
B Lower Columbia above Bonneville	4	0	0	0	4	8
C Middle Columbia	2	0	0	7	1	10
D Upper Columbia	7	0	1	2	8	17
E Lower Snake	5	0	0	0	4	9
Upper Snake	10	0	0	0	4	14
Total Columbia Basin	35	0	6	10	27	78

Sources: Corps of Engineers (1975): Bonneville Power Administration (1980); Heitz et al. (1980); and Washington State Department of Ecology (1981); Bonneville Power Administration (1983); Corps of Engineers (1984).

[1]Includes only major (equal to or greater than 5 megawatts) projects in the upper Columbia River Basin in British Columbia.

[2]Includes only major (equal to or greater than 5 megawatts) projects in the Upper Snake River Basin above Shoshone Falls.

The percentage of appropriated funds for federal multipurpose projects provides an indication of the purpose of operation. The majority of funding allocated for federal projects has been targeted for power production (Table 24). On 15 of 21 major federal projects, over 50 percent of the funds were allocated for power production. Although multipurpose in nature, most Corps of Engineers project investments were targeted primarily for hydroelectric development of the Columbia River and its major tributaries. On a percentage basis, flood control and irrigation represent the other major purposes in descending order of investment.

Table 24 - Percentage of allocation of project investment (by use) for major federal Columbia River Basin dams 1983.[1]

Project (Operator)	Region[2]	Project Use(s), by Percent							Total $ Cost (millions)
		Power	Irrigaton	Flood Control	Navigation	Wildlife	Recreation	Other	
Boise (BOR)	S	12	66	22	--	--	--	--	77.2
Columbia Basin (BOR)	UC	57	38	2	1	0.2	.01	0.03	1,648.2
Minidoka (BOR)	S	7	60	30	--	1.4	0.3	--	84.8
Yakima (BOR)	MC	6	92	1	--	1.4	0.3	--	84.8
Albeni Falls (COE)	UC	95	--	0.5	0.4	--	4.0	--	33.8
Bonneville (COE)	LC	94	--	--	6	--	0.16	0.26	779.3
Chief Joseph (COE)	UC	98	0.15	--	--	--	0.43	0.97	486.1
Cougar (COE)	LC	30	5	63	1	--	--	0.3	60.6
Detroit-Big Cliff (COE)	LC	61	8	31	.03	--	--	--	67.2
Dworshak (COE)	S	84	--	10	3	--	3	--	352.4
Green Peter (COE)	LC	55	6	34	0.4	--	--	2	90.0
Hills Creek (COE)	LC	36	9	54	1.3	--	--	0.55	49.1
Ice Harbor (COE)	S	76	--	--	23	--	--	--	200.1
John Day (COE)	LC	74	--	4	16	--	2	5	538.9
Little Goose (COE)	S	78	--	--	20	--	1.6	1	257.7
Lookout Point/Dexter (COE)	LC	48	.15	50	0.7	--	0.5	0.1	96.1
Lower Granite (COE)	S	82	--	--	13	--	3	2	413.1
Lower Monumental (COE)	MC	81	--	--	17	--	1	0.15	275.9
McNary (COE)	LC	80	--	--	19	--	0.8	--	349.0
The Dalles (COE)	LC	86	--	--	13	--	0.6	--	325.9

[1]Source: Bonneville Power Administration (1983).

[2]LC = Lower Columbia, MC = Middle Columbia, UC = Upper Columbia, S = Snake.

The effects of hydropower development on salmon and steelhead resources in the Columbia River Basin can be related to two major activities: 1) construction and development, and 2) operation. Potential environmental effects are associated with all aspects of hydroelectric project development including the construction of the dam or diversion structure, a reservoir if one exists, penstock, powerhouse and building of access roads. All impacts, which are site-specific, can occur both at the project site and downstream.

The following paragraphs provide general information describing these two activities. The resulting impacts on anadromous fish, particularly salmon and steelhead, in the Columbia River Basin are provided in the following sections.

5.3.2 The Effects of Hydropower Development on Columbia Basin Salmon and Steelhead

The direct effects of the construction of hydroelectric and multipurpose dams that include hydropower on salmon and steelhead in the Columbia River Basin can be divided into four categories:

1. Blockage of habitat.
2. Alteration of habitat.
3. Barrier to or modification of juvenile migration.
4. Barrier to or modification of adult migration.

Where no fish passage facilities have been provided, hydroelectric dams totally block anadromous fish runs on the river. In addition, dams inundate spawning and rearing habitat. Figure 5 shows areas that have been blocked by dams, thus preventing access of salmon and steelhead to natural spawning areas. Fulton (1968, 1970) compared the historical range of salmon and steelhead with the present range in the Columbia River Basin (see Appendix B). More than 55 percent of the Columbia River Basin accessible to salmon and steelhead before about 1939 has been blocked by large dams, many of which are operated exclusively or largely for generating electrical power (Thompson 1976b).

One indication of historical trends in salmonid habitat alteration by hydroelectric dams and multipurpose dams is the total amount of water stored by hydroelectric dams (total storage capacities). Total storage capacity ranges from zero storage for exclusive hydropower dams in the Snake River area below Hells Canyon Dam to over 47.5 million acre-feet in the upper Columbia River above Chief Joseph Dam area (Table 25). Overall, the six areas in the Columbia River Basin have a total hydroelectric storage capacity of over 74.9 million acre-feet. This total storage capacity is equivalent to about 56 percent of the 1929-1978 average annual modified runoff volume of the Columbia River at The Dalles.

Table 25 - Storage capacity of hydroelectric dams and multipurpose dams in the Columbia River Basin.[1]

Area	Total Storage Capacity[2] (acre-feet) Hydroelectric Dams	% Total	Multipurpose Dams	% Total
A. Columbia River below Bonneville Dam	69,200	14.2	5,216,600	7.0
B. Columbia River between Bonneville Dam and Snake River confluence	37,400	7.6	5,349,400	7.2
C. Columbia River between Snake River and Chief Joseph Dam	2,400	0.5	3,116,500	4.2
D. Columbia River above Chief Joseph Dam[3]	134,800	27.5	47,526,700	63.8
E. Snake River below Hells Canyon Dam	0	0	5,350,100	7.2
F. Snake River above Hells Canyon Dam[4]	246,100	50.2	7,869,960	10.6
Total Columbia Basin	489,900	100.0	74,429,300	100.0

Sources: COE (1975); WSDE (1981); BPA (1980); Heitz et al. (1980); BPA (1983); COE (1984).

[1]Calculated from information presented in Appendix C.

[2]Includes active and inactive storage capacity.

[3]Includes only major projects (equal to or greater than 5 megawatts) in the upper Columbia River Basin in British Columbia.

[4]Includes only major projects (equal to or greater than 5 megawatts) in the upper Snake River Basin above Shoshone Falls.

However, the total storage capacity figures listed above for hydroelectric projects is not entirely usable for hydropower purposes. For example, the storage capacity numbers listed include both active and inactive storage. Inactive storage is water that is stored below the level of the reservoir that can be run through the turbines or spilled. If all the active storage has flowed out of a reservoir, then only inactive storage will remain and this water cannot be released from the reservoir. Also, some of the storage space in Canadian projects was developed solely for use in Canada. Finally, reservoirs constructed for multipurpose use are operated to supply water for irrigation, flood control, navigation, domestic, municipal or industrial use, etc.

Another indicator of historical trends in salmonid habitat alteration by hydroelectric dam development is the cumulative storage capacity during five-year increments. This information is plotted, for both hydroelectric dams and multipurpose dams which include hydropower, for each of the six regions in Figures 20 and 21. Most of the cumulative storage capacity for hydroelectric dams in the basin occurred in the upper Snake River area when the Hells Canyon project added nearly 168,000 acre-feet of storage in 1967. The second largest increase in cumulative storage capacity for hydroelectric dams occurred in the upper Columbia River area above Chief Joseph Dam when 68,000 acre-feet were added by the Sevenmile project in 1979 and nearly 48,000 acre-feet were added during the 1950-1955 period (Figure 20). For the lower Columbia River area below Bonneville Dam, the greatest increase in storage capacity for hydroelectric dams occurred from 1955 to 1965 when nearly 42,000 acre-feet were added to the system (Figure 20). Pelton Dam, built on the Deschutes River in 1957, accounts for nearly all of the storage in the area of the Columbia River between Bonneville Dam and the Snake River. Pelton has a storage capacity of 37,300 acre-feet.

For multipurpose dams that include hydropower, the greatest increase in cumulative storage capacity occurred in the upper Columbia River area above Chief Joseph Dam, particularly after Mica and Libby dams became operational as a result of the Columbia River Treaty in the 1970s (Figure 21). These two multipurpose projects alone provide over 25.8 million acre-feet of storage. The second and third greatest increases in cumulative storage capacity also

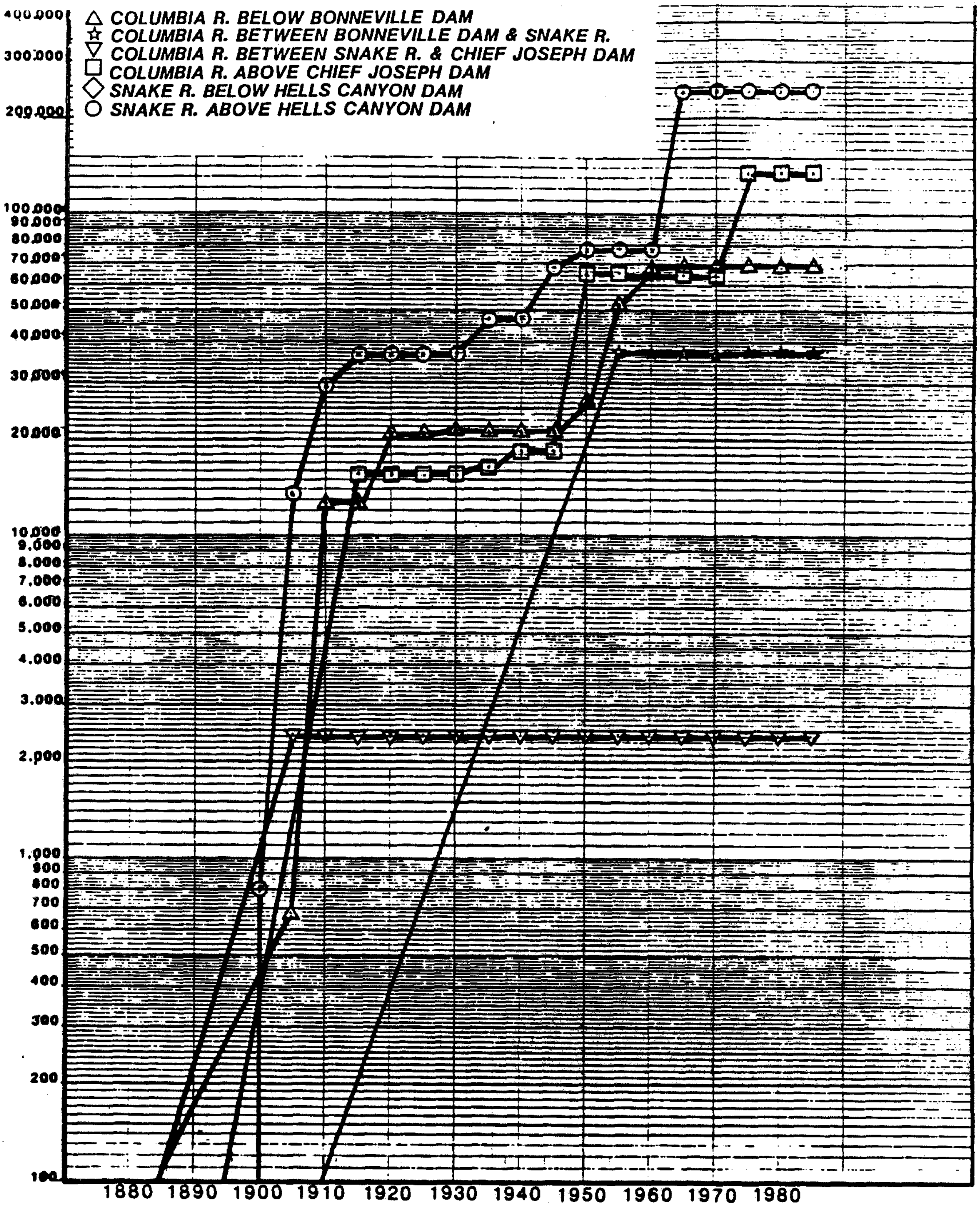

Figure 20. Cumulative storage capacity of strictly hydropower dams in the Columbia River Basin (COE 1975; WDOE 1981; COE 1984).

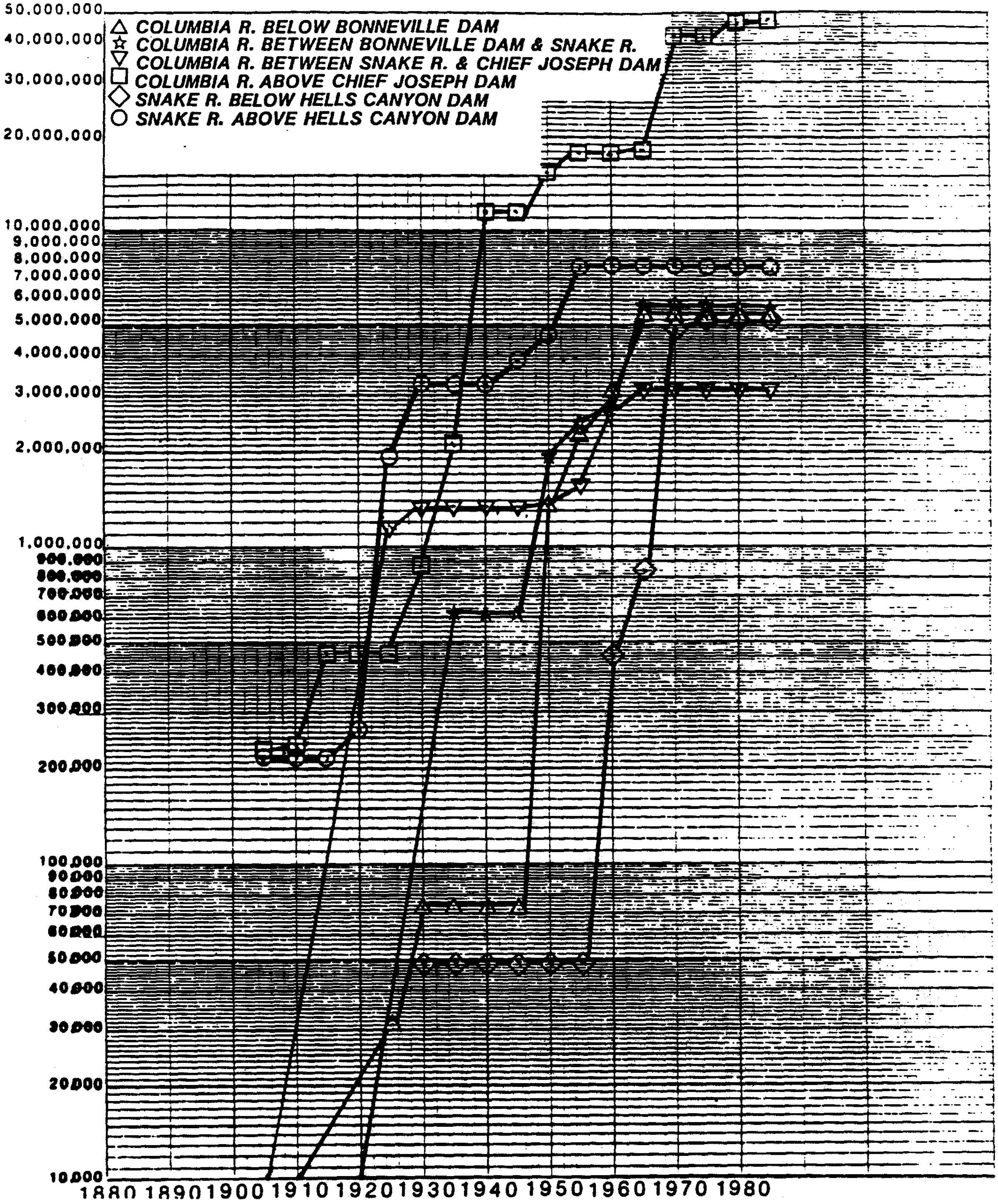

Figure 21. Cumulative storage capacity of multipurpose hydropower dams in the Columbia River Basin (COE 1975, WDOE 1981, COE 1984).

occurred in this area when Grand Coulee Dam was closed in 1941 (9.56 million acre-feet) and when Revelstoke became operational in 1983 (4.3 million acre-feet). The greatest increases in storage capacity for multipurpose projects in the two lower Columbia River areas and two Snake River areas occurred from 1950 to 1975, although a significant amount of storage capacity was added in the upper Snake River area above Hells Canyon Dam during the 1924-1932 period. The majority of multipurpose storage in the middle Columbia River area between the Snake River and Chief Joseph Dam occurred during two discrete periods, one from 1928 to 1933, and the other from 1959 to 1967 (Figure 21).

5.3.2.1 Run-of-River Projects

Much of the earliest and most recent hydroelectric development has been small run-of-river projects which use small, high gradient streams to produce electricity. Many of these small projects involve a low diversion structure within the streambed, and use a pipeline, canal, and/or pressure penstock to convey water to the powerhouse. Once the falling water is used to generate electricity, it is returned to the stream, usually somewhat downstream from the diversion point. A few projects involve construction of a new storage dam or a larger impoundment structure to divert the necessary flows and create the hydraulic head needed to produce energy. Finally, a number of projects use an existing dam and/or conduit to divert the water (Washington Department of Ecology 1985).

The actual construction of a dam or diversion structure has considerable potential for adverse environmental impact. Erosion and bed load (sediment) increases can occur when clearing the stream bank, blasting underlying bedrock, or during construction within the stream channel. Water quality standards may not be met, and other adverse impacts to anadromous fish and habitat may occur as a result of construction work within the stream channel, particularly during periods of low flow (Washington Department of Ecology, 1985).

5.3.2.2 Storage Projects

A number of large, multipurpose reservoir projects have been developed in the Columbia River Basin, most notably in the area of the Columbia River above Chief Joseph Dam. Large storage projects can cause significant environmental impacts of a different nature. A reservoir has low water velocity, which may result in changes in water temperature, dissolved oxygen levels, turbidity, water chemistry, and aquatic habitat. In deep reservoirs, thermal and chemical stratification is likely to occur with potentially significant effects on the aquatic life in and downstream of the reservoir. Downstream effects can be beneficial or adverse, depending on the site, water quality, size of reservoir and facility design (Washington Department of Ecology 1985).

In general, creation of a reservoir transforms an ecosystem dependent on moving water into one dependent on still water. This results in substantial changes in the distribution, abundance, and diversity of organisms and in the carrying capacity of the habitat. Also, it has the potential for increased predation of juvenile salmon and steelhead.

Impacts on salmon and steelhead related to creation of reservoirs behind dams also include inundation of important spawning areas. For example, Wells Dam flooded important spawning areas for summer chinook in the mainstem of the middle Columbia River area. This resulted in a drastic decline in chinook redds after 1967 (Appendix A, Figure A-91). John Day and McNary dams inundated a total of 137 miles of important fall chinook spawning areas in the mainstem of the Columbia River.

Finally, water temperatures increase during the summer because of the greater surface area of large storage impoundments. Collins (1976) reported that conditions in the Brownlee Dam reservoir are too severe for young salmonids. A high degree of thermal stratification develops in the reservoir with surface temperatures reaching lethal levels while the cooler subsurface water becomes deficient in oxygen. Most mainstem Columbia and Snake river impoundments, other than Grand Coulee, are run-of-river impoundments in which daily flow-through represents a significant fraction of each reservoir's storage capacity. This feature limits significant thermal stratification effects in mainstem run-of-river reservoirs.

Flows and river temperatures in the mainstem Columbia River, however, are influenced by releases from Grand Coulee Dam. For example, releases at Grand Coulee Dam trigger releases at all downriver dams since their active storage capacities are limited. This accounts for the "river run" designation of the mainstem reservoirs below Grand Coulee Dam. The existing reservoir system has caused no significant change in the average annual temperature of the mainstem Columbia River. However, storage and release of water from Lake Roosevelt since 1941 have delayed the timing of peak summer temperatures below Grand Coulee Dam. This delay is about 30 days at Rock Island Dam and is reflected, to a lesser extent, as far downstream as Bonneville Dam. The mainstem reservoir complex has moderately high and low extremes so that river temperatures are now slightly lower in summer and slightly higher in winter (Jaske and Goebel 1967, Jaske 1969, Jaske and Synoground 1970). Seasonal temperatures in the mid-Columbia River (below Priest Rapids Dam) from 1965 to 1983 peaked near $20^{o}C$ (Whelan and Newbill 1983).

5.3.2.3 Mainstem Hydroelectric Projects

Except for sockeye salmon, which require a lake nursery area for their freshwater rearing habitat, salmon and steelhead have evolved in a free-flowing river environment. The predevelopment riverine ecology provided generally favorable conditions permitting juvenile anadromous fish to survive and enter the ocean to feed and grow, as well as favorable conditions for adults to return to natal streams and spawn. The riverine ecology of the Columbia and Snake rivers and many of their major tributaries has been altered significantly by dam development in less than half a century (Ebel et al. 1979). For example, upriver salmon and steelhead in the mainstem Snake and Columbia rivers are now confronted with up to eight or nine large impoundments and dams to pass, during their downstream and upstream migrations.

Development of multipurpose dams and hydroelectric projects on the mainstem Columbia and Snake rivers has greatly altered the natural flows in the Columbia River drainage. Runoff during the spring is stored in large headwater reservoirs for use during periods of naturally low flows. While regulating the river in this fashion increases the energy production capability, it changes the natural runoff pattern. In particular, hydroelectric regulation reduces river flows during the spring when juvenile salmon and steelhead are migrating downstream to the ocean. A major consequence of dam development and reservoir storage on the mainstem Columbia and Snake rivers is a reduction in flows and an increase in the cross-sectional area of river, resulting in delays in downstream migration.

The effects of a series of impoundments and barriers on the timing of migrating fish to optimal ocean and spawning ground conditions are not completely understood (Ebel et al. 1979), but data from Raymond (1968a, 1968b, 1969) indicate that juvenile chinook salmon now migrate about one-third as fast through impounded reaches of the river as through the few remaining free-flowing reaches. During low flow years, Ebel et al. (1979) estimate that juvenile chinook salmon and steelhead migrating from the Salmon River will take 78 days to reach the Columbia River estuary, arriving about 40 to 50 days later than they did before all the dams were constructed. The impoundment of water in headwater storage reservoirs and the regulation of river flows by mainstem run-of-river dams has more than doubled the time required for the hazardous migration to the sea.

Reservoir lengths of mainstem Columbia and Snake River dams range from one mile for the Upper Salmon B project on the Snake River to 151 miles for the Grand Coulee project on the Columbia River (Table 21). Reservoir lengths and capacities are directly related to fish passage time (Bell et al. 1976).

As noted above, the total biological effect of these significant changes in the time of migration of juvenile anadromous fish is not yet completely understood. It has been suggested that an immediate effect in low-flow years is a tendency for some juveniles to stop migrating to sea and spend several months in fresh water before re-smolting and migrating to saltwater. Some of these fish, however, spend the rest of their lives in fresh water, never becoming a productive member of their species. Thus, this increase in travel time affects the ability of the juvenile salmon to make a successful transition from freshwater to saltwater. Of even greater consequences are the effects of increased mortality due to prolonged exposure to predatory fish and birds. As a result of reduced flow rate and therefore longer exposure to the sun, river temperatures and higher dissolved oxygen levels in the water are lower. These and associated changes in the water chemistry, along with increased exposure to pollutants, stresses fish and causes greater susceptibility to disease (Ebel et al. 1979).

Adults migrating to natal spawning grounds also are delayed at dams during high-flow years, due to their difficulty in locating fish ladder attraction flows. This can result in increased exposure to nitrogen supersaturation which has caused direct mortality to fish (Beiningen and Ebel, 1970). Delayed indirect mortality from increased incidence of disease caused by prior exposure to high nitrogen superstaturation also has been measured (Ebel et al. 1975).

5.3.3 The Effects of Hydropower Operation on Columbia River Basin Salmon and Steelhead

Operation of multipurpose projects has a systemwide effect on anadromous fish in the Columbia River Basin because of the integrated operation of the various federal projects to maximize efficiency in attaining power and flood control objectives. The Columbia River Treaty and Pacific Northwest Coordination Contract Agreement have strengthened the concept of a single system operation for hydropower, flood control and other purposes. System operational impacts on anadromous fish are primarily related to reduction of natural spring flows because of upstream storage and the maximization of power generation which limits the amount of spill available for reducing turbine related mortalities. A smaller spring freshet results in increased travel time to the ocean and, therefore, decreased survival for juvenile anadromous fish.

Operational impacts on salmonids of Columbia River Basin hydroelectric dams and multipurpose dams that include hydropower have been summarized as follows (Natural Resources Consultants 1981):

- o turbine mortalities;
- o delayed migration;
- o gas supersaturation of water;
- o combined effects resulting from regulated stream flows and temperature regimes;
- o susceptibility of outmigrants to predators; and
- o power peaking operations.

Any structure built within a stream channel has the potential to impede movement of aquatic organisms (especially anadromous fish) and sediment. This can be especially harmful to anadromous fish which rely on a flowing stream habitat for spawning, incubation, and rearing. An improperly designed or operated facility can result in significant mortality to juvenile fish migrating downstream and to adult fish migrating upstream to spawn (Washington Department of Ecology 1985).

A diversion structure can kill fish at the intake if water velocities are such that fish become trapped on the intake screen. If no screen exists, the fish may go through the hydraulic turbines, usually with high mortality rates. A poorly designed intake structure may trap air, resulting in high dissolved gas levels in the water released from the powerhouse site. This can cause a fatal condition in fish similar to "the bends" (Washington Department of Ecology 1985).

Furthermore, pipeline, canal, or penstock leakage can destablize slopes and lead to pipeline failure, land slides, or other mass wastage of slopes. Resulting erosion can hurt stream productivity.

One indication of the historical change in operation of hydroelectric facilities is cumulative power output. Trends in total cumulative power output for each of the six study areas in the Columbia River Basin are illustrated in Figure 22. Power output overall has increased from virtually nothing in 1884 to over 34,000 megawatts today. The upper Columbia River area above Chief Joseph Dam has shown the greatest cumulative power output in the basin. This is primarily the result of large, provincial/federal multipurpose dams such as Mica and Revelstoke in Canada, and Chief Joseph and Grand Coulee in the U.S.

Originally, when hydroelectric dams were constructed in the Northwest, upstream passage facilities for adult fish at the dams were considered adequate to sustain salmon and steelhead runs. Since that time, much concern and effort have shifted to provide safe downstream passage at the dams for juvenile salmonids. Once it has passed safely through the reservoir, the smolt must negotiate the physical barrier of the dam. The fish will either pass over the spillway (if water is being spilled) or be drawn by the flow through the turbines.

With present operating conditions and spill levels, the most hazardous course for juvenile salmon and steelhead is to pass through the turbine. Studies have shown that as juvenile salmonids are drawn through the power turbines, they are subjected to a variety of conditions that can cause injury and death. Rapid changes in pressure, physical strikes, and cavitation

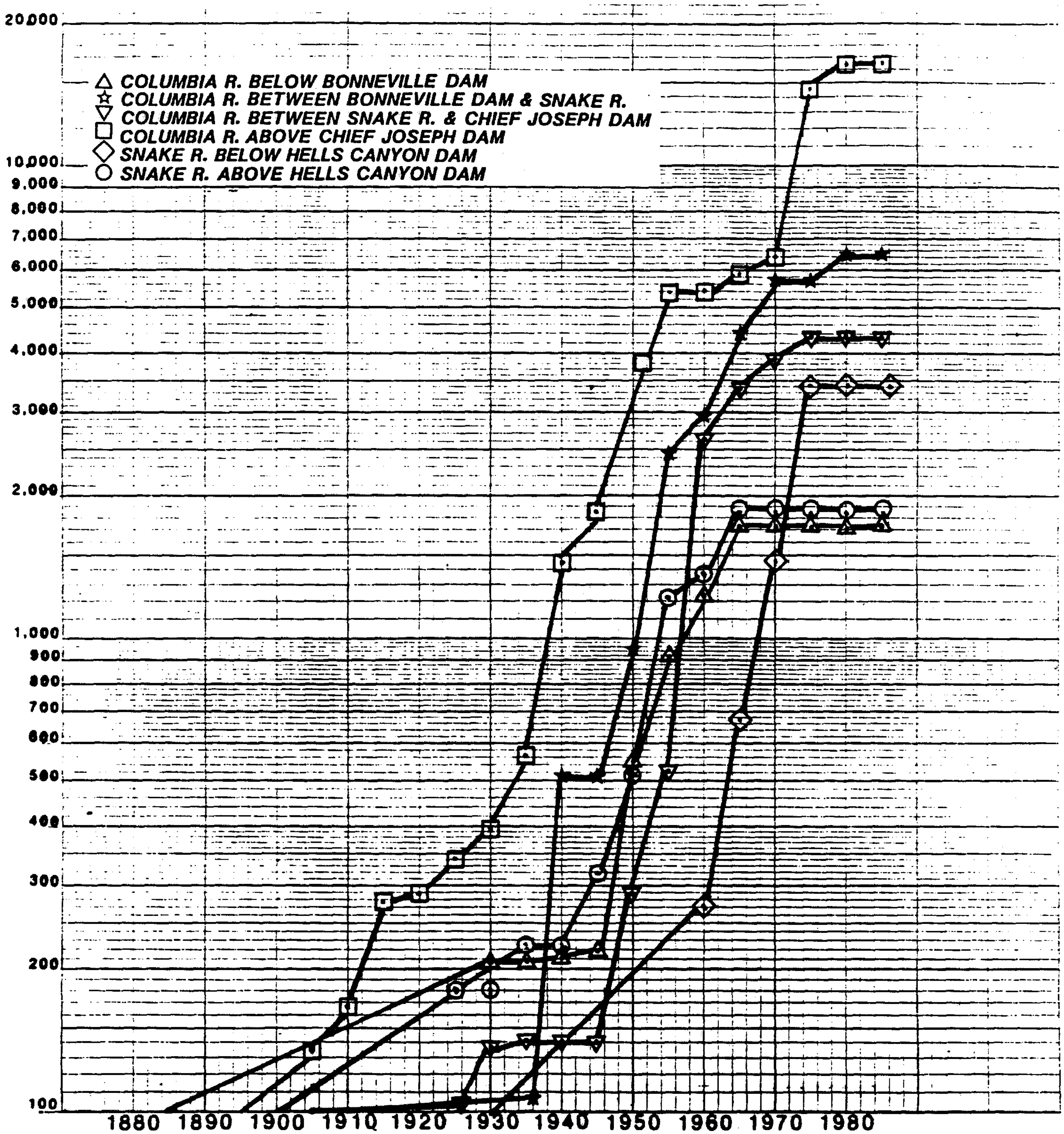

Figure 22. Total cumulative power output in the Columbia River Basin (COE 1975; Heitz et al. 1980; BPA 1980; WDOE 1981; BPA 1983; COE 1983).

within each turbine are the major contributors to juvenile mortality as the fish pass from the top of the dam through the turbine intake and out a tunnel at the base of the dam. Cavitation is defined as the formation of voids around a body in a liquid when the local pressure is lower than vapor pressure (U.S. Department of Interior 1975). The moving turbine blades and shearing action of the water in the turbine also can cause injuries or death. Also, juvenile salmonids become stunned and disoriented as they move through the turbines, thus increasing their vulnerability to predators, especially squawfish and sea gulls, which are abundant in the backroll of the turbine discharge at the base of most dams.

Mortality rates of juvenile salmonids at individual dams depend on many factors, including relative amounts of water passing through the powerhouse (turbine efficiency) and spillway; the size, species, and condition of the fish; the type of turbine; the operating load; and pertinent plant characteristics (Collins 1976), (Bell et al. 1967). Schoeneman, Pressey and Junge (1961) estimated the mortality rate of juvenile chinook salmon passing over the spillway to be about 2 percent; and the direct mortality of salmonids passing through turbines, such as those found on the Columbia and Snake rivers, to be about 11 percent. Other authors report juvenile fish mortality estimates of 15 percent per dam as conservative (Junge 1980; Collins 1976). Chaney and Perry (1976) reported that juvenile salmonid mortalities average 15 to 20 percent at each mainstem dam, depending on flow conditions. Studies by Long et al. (1968, 1975) showed mortalities as high as 30 percent for juvenile coho salmon passing through turbines at Ice Harbor and Lower Monumental dams on the Snake River when indirect mortality for predation was included. Losses from predation vary from dam to dam and year to year depending on the fluctuating populations of predators. However, when the predation loss at dams is combined with the direct loss in turbines, it is apparent that the turbine-related mortality occurring to a population of downstream migrants passing over a long series of dams can be significant. For example, in the low-flow years of 1973 and 1977 when almost all of the juvenile migrants had to pass through turbines, losses of 95 percent and 99 percent, respectively, were estimated for Snake River spring chinook salmon and steelhead (Sims et al. 1978).

These losses are compounded by the number of dams through which fish must pass. Assuming a range of 15 to 30 percent juvenile mortality and 5 to 10 percent adult mortality per dam, cumulative percentage mortalities are indicated in Table 26. (This assumption is used only for the purpose of illustration since actual mortalities may be higher or lower depending on project design, fish species, and the use of mitigative measures such as transportation.) Therefore, if 100 juvenile salmonids began their downstream migration above Wells Dam on the Columbia River, the cumulative mortality of passing a series of nine dams would result in only four to 23 fish surviving to below Bonneville Dam. If 100 adults began their migration upstream from below Bonneville Dam, the cumulative mortality of passing nine dams would result in from 39 to 63 fish surviving to above Wells Dam. From a historical perspective, the cumulative mortality rate for downstream juvenile migrants has increased with the completion of each mainstem dam since Rock Island Dam was built in 1933.

Table 26 - Cumulative juvenile and adult salmonid mortalities at dams.

Number of Dams	Cumulative Mortality 1	2	3	4	5	6	7	8	9
JUVENILES									
15 percent average mortality per dam	15	28	39	48	56	62	68	73	77
30 percent average mortality per dam	30	51	66	76	83	88	92	94	96
ADULTS									
5 percent average mortality per dam	5	10	14	19	23	26	30	34	37
10 percent average mortality per dam	10	19	27	34	41	47	52	57	61

Hydroelectric dams and multipurpose dams also can create a condition where the water becomes supersaturated with gases. This is frequently referred to as "nitrogen supersaturation" because air is nearly four-fifths nitrogen. This condition is lethal to fish at high levels of gas pressure (Collins 1976). It occurs when large volumes of water plunge over a spillway into a deep pool below the dam forcing entrapped air into solution with water. The gases are continually dissolved and added to the water as long as the spilling continues. Fish trapped in supersaturated water suffer from "gas bubble disease." Dissolved gases are adsorbed in the bloodstream and air bubbles are formed when the gases leave solution. Mortalities created by supersaturation have been high for both adult and juvenile salmonids in high flow, high spill years. High total dissolved gas levels (exceeding 130 percent saturation) occurred during the late 1960s and early 1970s on the mainstem Columbia and Snake rivers due to large amounts of spilled water in high flow years because there was neither adequate upstream storage nor sufficient powerhouse capacities to control the flow. The severity of gas bubble disease and its consequences depend on the level of supersaturation, the duration of exposure, water temperature, general condition of the fish, and swimming depth maintained by the fish (Ebel and Raymond 1976).

Another operational impact of hydroelectric dams and multipurpose dams on salmonids is the combined impact of altered stream flows on the migration rate of juvenile salmonids and exposure to supersaturated water. As discussed earlier, migration rate is related to stream flow (i.e., higher water velocity results in higher rate of fish migration) (Ebel and Raymond 1976). Delays in outmigration of juvenile salmonids can result in extended exposure to supersaturated water during some high flow years. Ebel and Raymond (1976) found that survival of juvenile chinook salmon and steelhead decreased in the Snake River to Ice Harbor Dam from over 90 percent through 1968 to about 70-75 percent in 1969. This decline was related to increased exposure to higher nitrogen supersaturation. Survival of chinook smolts, however, from Ice Harbor Dam to The Dalles Dam in 1969 was slightly higher than in previous years (67 percent). Conversely, lower steelhead survival was attributed to increased exposure to supersaturated water in the Columbia River. Most yearling chinook migrated downstream in April and early May when flows were 80,000 to 100,000 cubic feet per second in the Snake River and about 300,000 cubic feet per second in the Columbia River. Steelhead migrated two weeks later when flows were higher. Thus, steelhead were exposed longer to higher levels of supersaturation and consequently suffered higher mortality than chinook salmon in this stretch of river. Spillway deflectors have been installed at most of the mainstem Columbia and Snake river dams to reduce nitrogen supersaturation, and total dissolved gas levels now are monitored closely throughout the smolt migration period. However, at very high spill levels spillway deflectors become ineffective.

Fish passage facilities have been constructed at many dams to provide access for adult anadromous salmonids migrating from the ocean to upstream spawning areas. Flows and spills also have been adapted to provide maximum attraction and unimpeded passage for adults. However, some adult fish passageways are not designed, operated or maintained adequately, and flow and spill conditions at the base of some dams (e.g., mainstem Columbia River and Snake River) can discourage fish movement in the river or mask fishway attraction flows. These factors result in delayed upstream migration as fish search for and ascend fish ladders. This has resulted in significant pre-spawning mortality of adult fish and reduced success of late spawners. Weiss (1970) observed that chinook salmon suffered mortalities of about 13 percent during both spring and summer periods of 1970 in passing Bonneville Dam, and from 12 to 25 percent mortality in passing The Dalles Dam in 1970. Gibson et al. (1979) state that adult salmonid mortalities in migrating past the four lower Columbia River dams can be related to flow. Except for John Day Dam, estimated losses are correlated highly with flow, with no significant loss for average flows of about 150,00 cubic feet per second. At John Day Dam an adult mortality of about 20 percent occurs independently of flow (Gibson et al. 1979). Passage delays at individual dams can range from two to four days for adult salmon (Van Hyning 1973).

Columbia and Snake river hydroelectric dams are used presently to provide about 80 percent of the firm, or base, energy supply in the Pacific Northwest, while thermal electric plants provide about 20 percent of the firm energy supply. Increased use of the hydropower system to provide power during peak demand periods could result from numerous factors, some of which include installation and operation of additional turbine units; overloading and partial loading of all units; increases in future power loads; use of additional storage now or in the future; changes in water levels (and frequency of changes) in the forebays of existing plants; installation of more thermal generating plants; and expansion of the Northwest-Southwest intertie system (Bell et al. 1976).

Since the beginning of operation of Rock Island Dam in 1933 and Bonneville Dam in 1938, not only have additional dams been constructed in the Columbia and Snake rivers, but additional units have been installed and operated at most of the projects. The addition of turbine units has reduced the amount of spill and provided additional peaking capability, allowing more water and fish to pass through the powerhouse, where the fish are vulnerable to turbine mortality discussed previously.

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Potential adverse effects on downstream migrant survival that cannot be measured due to under- or overloading turbine units during power peaking operations include unequal distribution of velocities and localized low pressure areas in the water column and over blade faces. Although unequal draft tube velocities, can be measured, there are no measurements available to describe surging velocities and pressure differences, all of which can introduce a differential smolt mortality rate in a turbine (Bell et al. 1976). Generally, the level of fish survival is directly related to the turbine efficiency curve. Therefore, it is desirable that turbines be operated at their maximum point of efficiency for a given head to maintain a low level of fish mortality (Bell et al. 1976).

5.3.4 Reducing the Adverse Effects of Hydropower Development and Operations

Programs for reducing the adverse effects of hydropower development and operations in the Columbia River Basin have involved a variety of efforts to compensate for salmon and steelhead losses. Two major areas of emphasis have focused on the upstream passage of adults and downstream passage for smolts. Safe adult passage was studied intensely during pre-Bonneville Dam times to develop effective facilities. Providing downstream passage of smolts through or over the dams proved to be a more complex problem than upstream passage.

Many of the hatcheries developed in drainage systems were eliminated from production by a given dam. Detailed information on many of these programs is presented in Chapter 6.

Many mitigation measures have been used to reduce impacts on salmonids resulting from hydropower and multi-purpose dams. A partial listing includes the following:

- Fish ladders;
- Fish lifts (elevators);
- Artificial spawning channels;
- Hatcheries and rearing facilities;
- Fish guidance measures (attraction flow, artificial lighting, etc.);

- Screening of gatewells and turbine intakes (traveling wire mesh screens, fixed screens, etc.). Presently, two Snake River and three mainstem Columbia dams have submersible traveling screens containing bypass and collection devices. There are plans for retrofitting other dams;

- Fish bypass and collection systems (bypass smolts around dams). Two Snake River and one mainstem Columbia River dam presently have fish transportation and collection facilities: Lower Granite and Little Goose on the Snake and McNary and Priest Rapids dams on the Columbia;

- Collection, barging and trucking of smolts downstream below Bonneville Dam;

- Installation of spillway deflectors (reduce nitrogen supersaturation);

- Controlled spill for moving smolts downstream over the dams;

- Flow augmentation by the Water Budget to "flush" smolts downstream during the spring outmigration to decrease travel time and increase survival;

- Streamflow regulation studies to assess effects of power peaking and flow manipulation;

- Evaluation of predator impacts on downstream migrating smolts (with consideration of means for eradication);

- Studies to determine optimum sizes and times for release of smolts from hatcheries;

- Evaluations of disease problems and measures for immunization in hatcheries;

- Habitat improvement and enhancement work in tributaries;

- Smolt studies to evaluate sources of stress in fish handling and bypass systems.

It is important to note that not all of the measures identified above reduce impacts in all instances, and none completely alleviate all adverse impacts in any specific instance.

Another major program designed to reduce the adverse effects of hydropower on Columbia Basin salmon and steelhead is the transport of smolts to a point below Bonneville Dam. This program was initiated in 1968 at Ice Harbor Dam as a trial experiment (Phinney 1976). Experiments with the results of transported fish continued in the 1970s at Little Goose Dam, and a massive program was initiated in 1975. In 1983, more than 7.5 million juvenile salmonids were transported to a point below Bonneville Dam with collections at Lower Granite Dam of over 2.3 million fish, at Little Goose Dam of over 0.8 million fish, and at McNary Dam of over 4.3 million fish (Delarm et al. 1984). Barge transport was used for 63 percent of the fish; trucking accounted for 37 percent.

5.3.5 The Current Status of Hydropower Impacts on Fish

Delays in outmigration of junveniles and in upstream migration of adults continue to occur in the Columbia River Basin. Long reservoirs and reduced river flows increase travel time for juvenile salmon and steelhead. Poorly designed fishways and flow and spill conditions at the base of some dams (e.g., mainstem Columbia River and Snake River) result in significant prespawning mortality of adult fish (about 5 percent per mainstem dam). Extended migration times also increase exposure to disease, predation, high water temperatures, and supersaturated gases. Juvenile mortality losses are compounded by the number of dams through which they must pass.

Large mainstem dams without fishway facilities, such as Chief Joseph and Hells Canyon, continue to block access to formerly important spawning and rearing areas in the Columbia River Basin.

The last major hydroelectric project (Lower Granite Dam) was constructed on the mainstem Snake River in 1975. However, cumulative power output and storage capacity has changed with the addition of new turbine units and powerhouses at existing dams. Increased power peaking has resulted in greater reservoir fluctuations that strand juvenile salmonids. Reservoir fluctuations also influence stream flows that affect migration. More attention is being given to water releases that consider the instream flow requirements of anadromous salmonids.

5.4 LOGGING

5.4.1 Overview

The forest industry of the Columbia River Basin has accounted for a substantial portion of the basin's economy. Logging probably was the first non-Indian industry to develop in the basin, with the earliest activity begun by the Hudson Bay Company in 1827 (Thompson 1976b). By 1850, 37 sawmills were operating in the Northwest, most of which were located near the mouths of the Columbia and Willamette rivers (Geppert 1984).

During the late 1800s, logging practices ranged from selective cutting to clear-cutting, depending upon demand. Logging activities were mainly confined to lowland areas and resulted in relatively little soil disturbance. However, as logging expanded inland to steeper terrain, the resulting disturbances accelerated erosion and stream sedimentation.

Transportation of cut logs was a major problem in the early logging days (1880-1920). The most efficient means to transport the logs was to float large rafts of logs down the nearest waterways to the mills. Splash, roll, and pond dams were used extensively during this time (Geppert 1984). Generally, these dams were constructed of logs and designed to impound a sufficient supply of water to move logs downstream (Geppert 1984). Once the pond was sufficiently full of logs, the dam was breached and the surge of water helped to flush the logs downstream to the tidal waters, where they were guided to the nearby saw mills. According to Sedell (1982), approximately 56 splash dams were constructed in the western Washington portion of the Columbia River Basin from 1880 to 1910, while about 55 splash dams were built in the Willamette and Deschutes drainages of Oregon during this same period.

To accommodate the logs' downstream passage, instream modifications had to be made, such as blocking sloughs, swamps, and low banks with log cribbing to keep logs in the main channel; blasting mainstream obstructions, such as sunken logs or large boulders; and removing debris accumulations. These practices dramatically changed the substrate, banks, morphology and riparian areas of streams used for log transportation. Streams that were most severely degraded included those in the Willamette and Deschutes basins in Oregon and most streams in western Washington.

During and after World War II, logging production in the basin increased significantly. Logging operations continued to move farther inland and larger, more sophisticated equipment was used. Road construction and associated logging operations often occurred on steeper slopes, which resulted in increased erosion and stream sedimentation (Thompson 1976b).

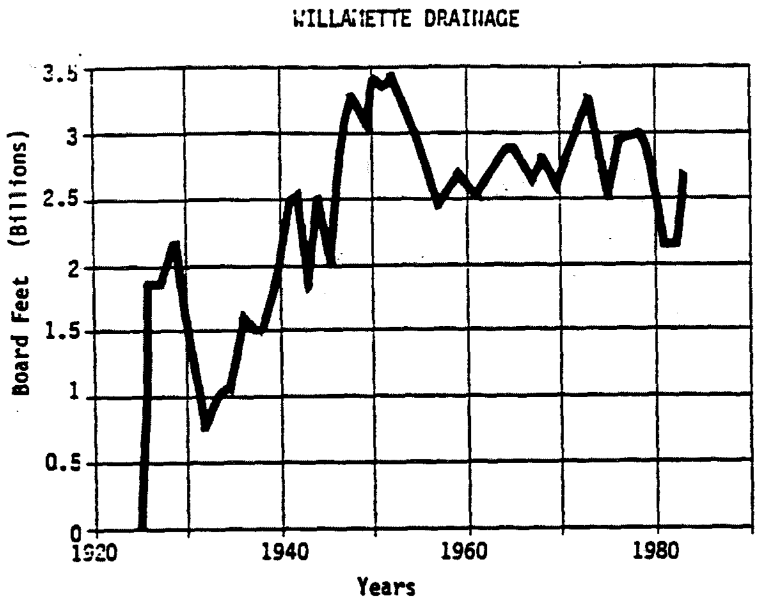
These developments in logging had several impacts on fish. The major one is the blockage of habitat caused by construction of logging roads. A second major impact is the loss of habitat complexity (reduction in types of habitat available) caused by removal of large woody debris from the stream course.

Other impacts on aquatic habitat due to forest industry activities include sedimentation (smothering of spawning gravels); degradation of water quality (increased water temperatures and decreased dissolved oxygen); and creation of barriers to anadromous fish migration (by debris dams) (Thompson 1976b). Logging practices also have reduced rearing habitat for juvenile salmonids and generally have contributed to decreased salmonid productivity in these streams (Sedell 1982). Log dams often delayed the upstream migration of adult salmonids and affected the downstream migration of smolts. Recent intensive forest management practices involving aerial applications of fertilizers, pesticide, and herbicides have increased the potential for widespread acute and chronic harm to aquatic communities.

The following sections describe logging development and related impacts to salmon and steelhead fisheries in the six Columbia River areas. The discussions of the two lower Columbia River areas and the two Snake River areas have been combined due to difficulties in separating data for these areas. Logging impacts are measured quantitatively in board-feet, because this is the only readily available statistic. However, because of differences among forests, logging production in board-feet between different geographic areas may not be totally comparable.

5.4.1.1 <u>Lower Columbia River</u>

Streams of the lower Columbia River area (all tributaries downstream of the Snake River confluence) probably have been affected more severely by the forest industry than other upstream areas. During the year in which the depression of 1929 started, the total board feet harvested in lower basin counties in Washington and Oregon was approximately 3.7 billion board feet, as compared to about 340 million board feet produced by counties in the middle and upper Columbia area and the Snake River area (Figures 23, 24, 25, 26). A particularly important subbasin in the lower Columbia is the Willamette, which also exhibited a higher total production than the middle Columbia, upper Columbia, and Snake River areas during this peak period of lumbering.



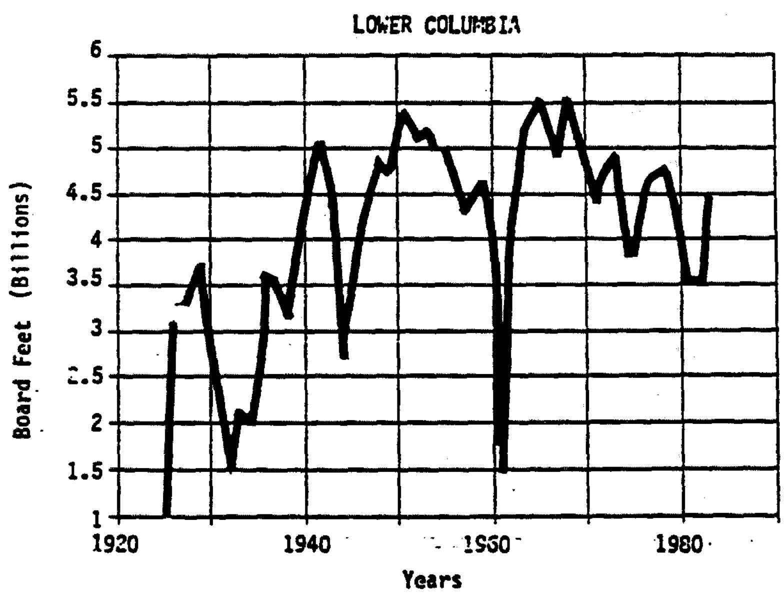


Figure 23. Logging production from 1925 to 1983 in Willamette River Drainage and lower Columbia River area (WDNR 1949-1983). (Discontinuous curve reflects data gaps.)

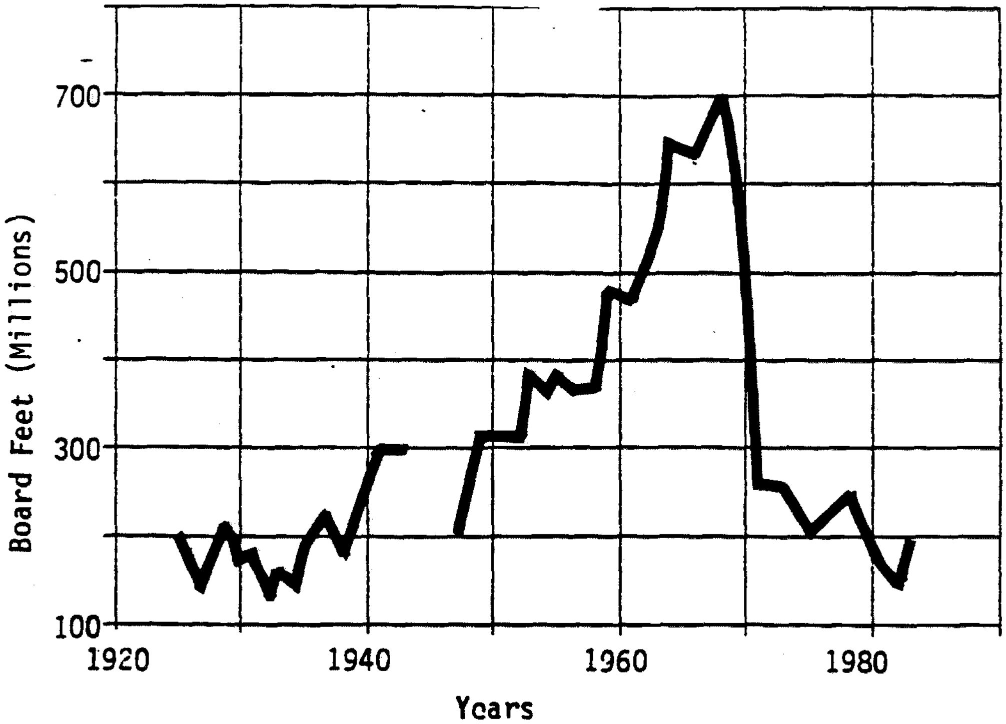


Figure 24. Logging production from 1925 to 1983 for the middle Columbia area (WDNR 1949 to 1983). (Discontinuous curves reflect data gaps.)

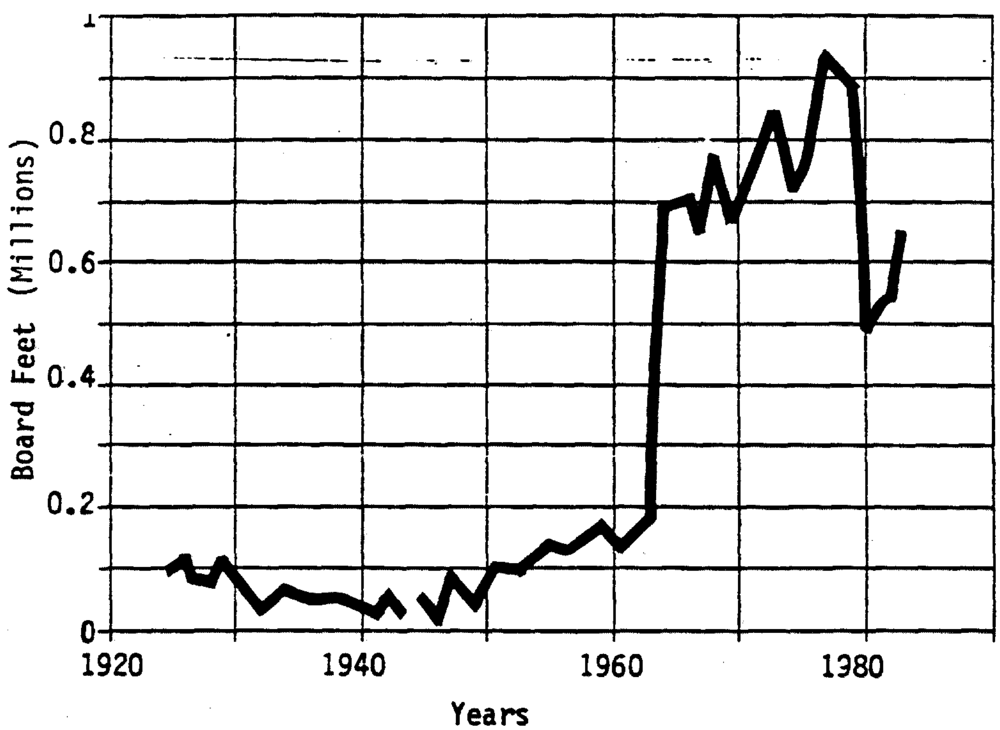


Figure 25. Logging production from 1925 to 1983 for the upper Columbia area (Pacific Northwest Forest and Range Experiment Station, 1972). (Discontinuous curve reflects data gaps.)

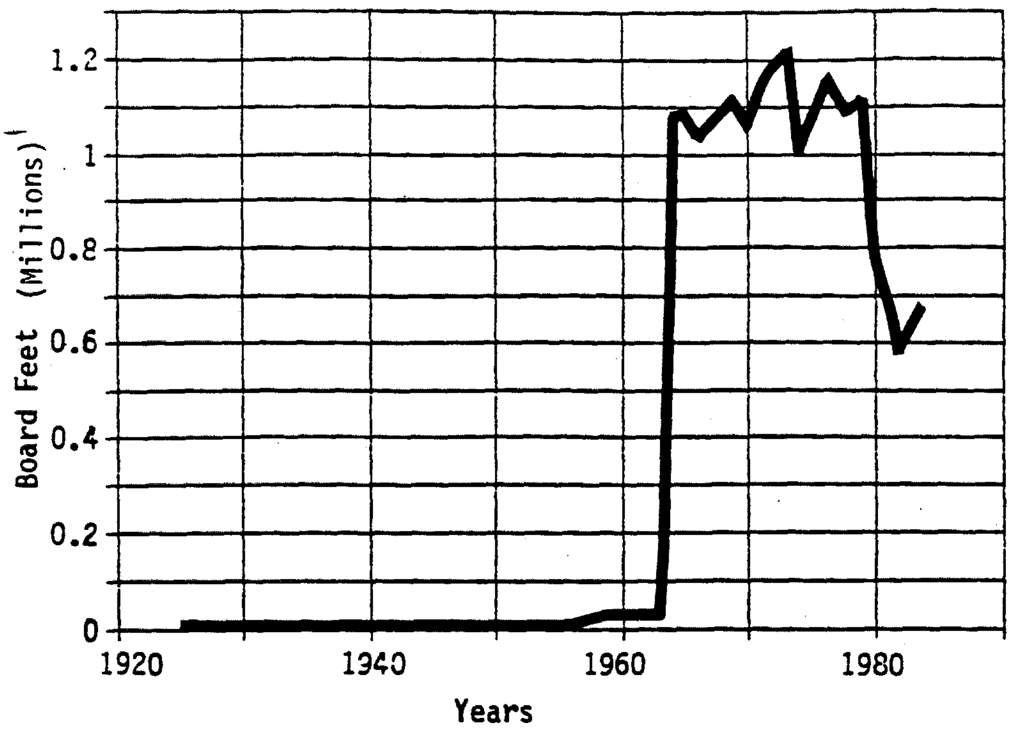


Figure 26. Logging production for the Snake River drainage 1925 to 1983 (Western Wood Products Association 1962-1983).

5.4.1.2 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

Logging production of counties in this area has been significantly less than in the lower Columbia River area (e.g., 215 million board feet versus 3.7 billion board feet in 1929, and 149 million board feet versus 4.4 billion board feet in 1983). Most of this area's lumbering activity occurred in the Yakima and Okanogan drainages (Pacific Northwest Forest and Range Experiment Station 1972).

5.4.1.3 Columbia River Above Chief Joseph Dam

Logging in this area was less extensive than in the area between the Snake's confluence and Chief Joseph Dam, until the 1960s when production was about equal. Logging in the Spokane Basin did not commence until after dams were constructed on this river so that power could be provided for sawmills (Scholz et al. 1985).

5.4.1.4 Snake River Area

Timber production data indicate that logging activity in the Snake River area was initially concentrated in the Tucannon River drainage (Pacific Northwest Range and Experiment Station 1972). Production statistics exist only for Columbia and Garfield counties in Washington from 1925 to 1964. In 1964, production statistics for Ada, Adams, Gem, Lemhi, Washington, Elmore, Valley and Boise counties in Idaho became available. Until the 1960s, logging production was relatively low, ranging from one million board feet in 1932 to about 30 million board feet in 1959. Current production (1983) appears to be in the 600-700 million board feet range. Both the historical and current production statistics are considerably below the production of the lower Columbia River area (Figures 23 through 26). Current production, however, is greater than the other two Columbia River areas (Figures 24 and 25).

5.4.2 Reducing the Adverse Effects of Logging

In 1905, the U.S. Forest Service (U.S. Department of Agriculture) was established to protect and manage production in the forests on federal land. The Washington State Board of Forest Commissioners was formed in 1905. In 1908, the Washington Forest Protection Association was established to protect the forest from wild fires. In 1911, the Weeks Act authorized the federal purchase of timber lands that had been clearcut to protect soil, check fires, conserve scenery, and manage the resources with a broad social view or multiple use concept.

An attempt to improve forest practices in the Columbia River Basin occurred in Washington when the Reforestation Act (RCW 84.28) was passed in 1931. However, the program was unsuccessful because of failure to raise the taxes that were to have funded the program. The Oregon Forest Practices Act (ORS 527.610 et seq.), Washington Forest Practices Act (RCWA 26.09.010 et seq.), and the Idaho Stream Protection Act (Idaho Code 42-3801) all provide for improved forest practices, but statutory law is not effective without strict enforcement. This enforcement is expensive and passage of these statutes has rarely been accompanied by appropriations of necessary funds.

In 1946, the "sustained yield" concept was established by the U.S. Forest Service. Under this concept, forested lands are managed to produce at levels commensurate with the production capacity of the land instead of managed based on external factors such as economic factors or demand for lumber. In order to achieve goals of timber production, cut-out areas are replanted in trees and certain limitations on harvest are imposed. Intensive forest management practices increased in the 1960s, including long-reach cable systems to reduce the need for additional roads.

Logging practices have changed for the better through time. The waterways are no longer used as transport corridors to market as they were in earlier times. This has eliminated the need for splash dams. In the last several years, the extensive use of buffer strips along streams has eliminated much of the damage that was once commonly caused to the aquatic environment. But logging in fragile soil areas and roads continues to cause sedimentation and associated problems for fish.

5.4.3 The Current Status of Logging Impacts on Fish

Not all detrimental impacts to anadromous fish habitat from logging activities have been eliminated. Current technology allows the elimination of many harmful effects of logging on salmon and steelhead if the proper techniques are used and the pertinent laws enforced. However, forest practices continue to have a significant impact on salmon and steelhead.

5.5 MINING

5.5.1 Overview

In the mid-1880s mining, primarily gold and silver, was the most important non-Indian industry in the Northwest. It also spurred other industries, such as logging, because mining resulted in a large population influx. By 1880, nearly all of the major hard rock (extracting minerals from the ground) mining districts had been discovered on the Salmon River, Boise River, Orofino Creek, John Day River, and Powder River. The majority of these districts are in the lower Snake River Basin. Other large mining districts within the Columbia River Basin included the Coeur d'Alene and Clark Fork areas; however, streams in these areas were not accessible to anadromous fish.

In the early days the predominant gold mining method was placer mining, which removed nuggets and fine gold particles from the stream bed itself and from bench deposits. Placer mining generally involves the agitation of gold-bearing deposits (i.e., stream gravels) so that gold particles, which are heavier than the surrounding rock debris, settle out. Water is then used to wash away the rock debris, leaving the gold particles behind. Several methods of placer mining were employed, including using a miner's pan, large sluice boxes, rocker cradles, and hydraulicking (hosing deposits with powerful jets of water). The most effective means of placer mining was dredging with large stream dredges. These dredges could process 1,000 to 15,000 cubic yards of gravel per day (Brooks and Ramp 1968). In some areas, especially in the Powder River drainage in Oregon, miners used large-scale placer dredging operations.

The following sections describe mining development and impacts to salmon and steelhead fisheries in the six Columbia River areas. The two lower Columbia River areas and the two Snake River areas analyses have been combined due to difficulties in separating data for these areas.

5.5.1.1 Lower Columbia River Area

Historically, gold and silver mining in the lower Columbia River area occurred mainly in the Willamette River drainage. Major mining districts included North Santiam and Quartzville on the Santiam Creek drainage; Blue River on both the Santiam and McKenzie Rivers; and Fall Creek and Bohemia on the McKenzie River. No major gold and silver mining districts were located in Washington within the lower Columbia River area.

Gold and silver mining in this area was done largely by underground methods and began around 1902. One of the major producing counties was Lane, which produced 34,000 ounces of gold and nearly 72,000 ounces of silver from 1902 to 1965 (Figure 27). This is relatively low production compared to other mining districts in northeastern Oregon and southwestern Idaho in the Snake River Basin (Figures 27 and 30).

Currently, there is very little gold and silver mining in the Willamette Basin. Mining in the lower Columbia area is mostly limited to small placer operations in the upper John Day Basin in Oregon, to one active gold mine in the Wind River drainage of southwestern Washington, and until its eruption in 1980, to the vicinity of Mount St. Helens, Washington.

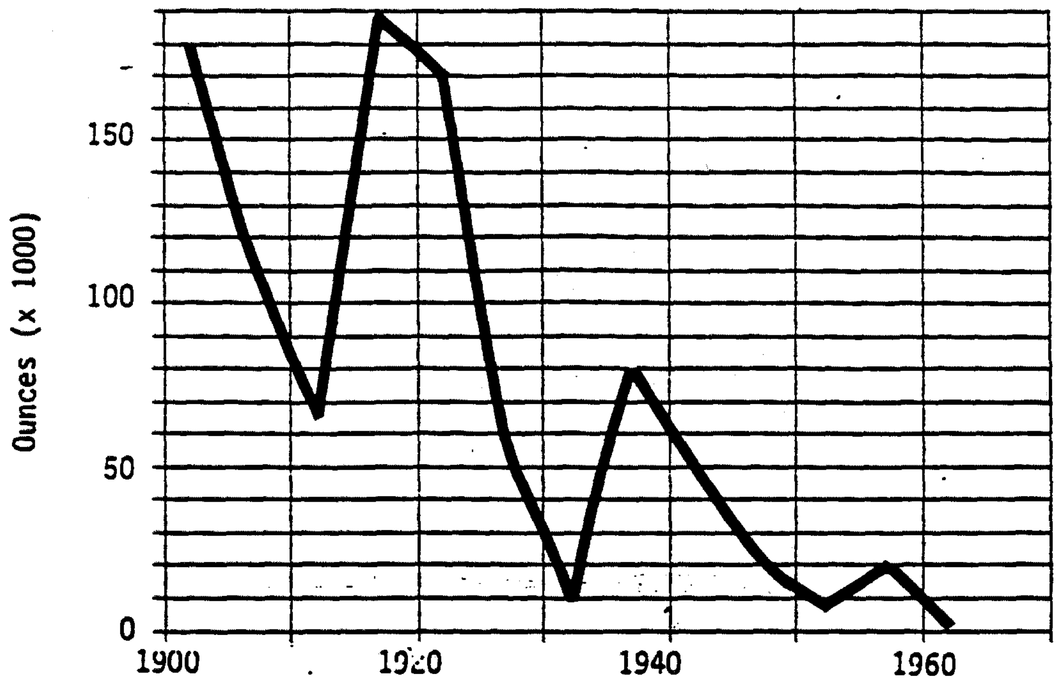


Figure 27. Gold and silver production in Oregon 1887-1962 (Brooks and Ramp, 1968).

Sand and gravel extraction from river beds is the other type of mining that occurs in this area. Presently, sand and gravel mining activities in the Willamette Basin (Figure 28) produce the greatest revenues and greatest land disturbance (Oregon State Water Resources Board 1963, 1965). The largest sand and gravel deposits occur near the mouth of the Willamette River near Portland, where approximately 40 to 70 million tons are available for mining (Oregon State Water Resources Board 1965).

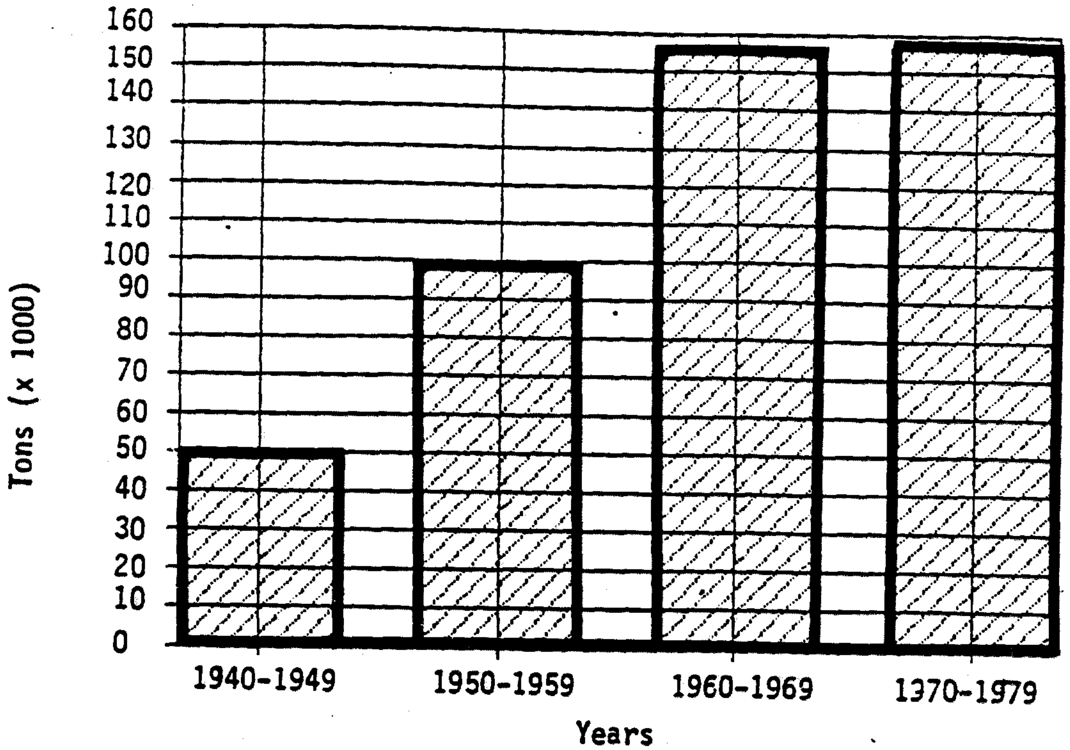


Figure 28. Sand and gravel production in Oregon 1940-1979 (Friedman et al., 1979).

Sand and gravel operations are the most prevalent mining activity in the Deschutes River drainage also. Other drainages with significant gravel mining activity include the Hood, John Day, and Umatilla in Oregon and the Cowlitz, Lewis, White Salmon, and Klickitat in Washington.

5.5.1.2 Columbia River Between Its Confluence With the Snake River and Chief Joseph Dam

This area consists of the Methow, Okanogan, Wenatchee, Chelan, Entiat, and Yakima drainages, all in Washington. Of these, mining was most prevalent in the Yakima, Okanogan, Entiat, and Chelan drainages. Most of Washington's gold and silver production occurred in counties in these drainages. Although placer mining was prevalent in the 1800s, underground mining dominated after 1900 (Koschman and Bergendahl 1968). Trends in gold and silver production in Washington from 1897 to 1982 are presented in Figure 29.

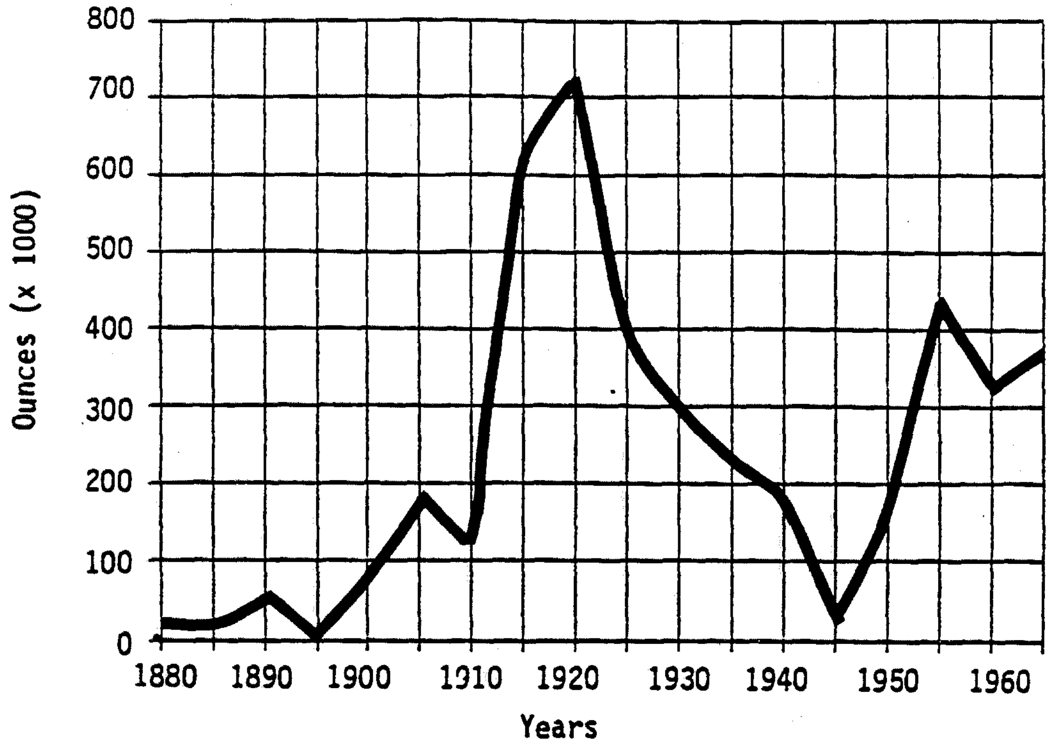


Figure 29. Gold and silver production in Washington 1887-1962 (Washington Department of Geology and Earth Resources 1985).

Gold was first discovered in Washington in the Yakima Valley; however, development was not extensive and existed primarily as placer mining up to 1900. Gold and silver mining in the Chelan, Okanogan, and Entiat drainages was mostly underground, with placer mining on tributary streams where deposits were economically recoverable. Therefore, disruption of streambeds and sedimentation due to placer mining probably was not extensive.

5.5.1.3 Columbia River Above Chief Joseph Dam

Considerable mining and degradation occurred in streams of the upper Columbia River area such as the Coeur d'Alene, Clark Fork and upper Kootenai rivers. However, few, if any, anadromous fish reached these areas because of passage barriers.

5.5.1.4 Snake River Area

The Snake River area encompasses most of Idaho, several important tributaries in northeastern Oregon, and some of southeastern Washington. The most prominent southern Idaho mining districts were located in the Salmon, Boise, and Clearwater drainages. Gold and silver mining in Idaho has been more extensive than in Washington or Oregon (Figure 30). In northeastern Oregon, the major districts were located on the Powder, Burnt, Malheur and Owyhee drainages (the Blue Mountains). No significant mining occurred in the Washington area of the Snake Basin. Gold and silver production from 1902 to 1965 for Oregon and Idaho is presented in Figures 27 and 30, respectively.

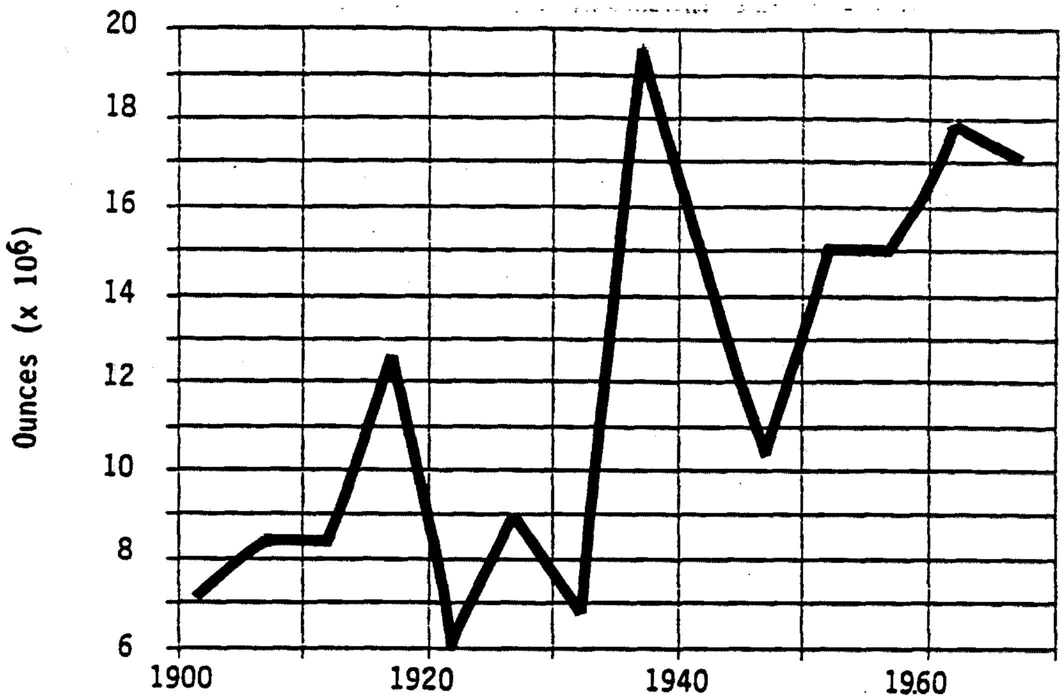


Figure 30. Silver and gold production in Idaho 1902-1967 (Idaho Mine Inspectors Annual Report, 1899-1974).

Placer mining in northeastern Oregon and southeastern Idaho began around 1860 (Brooks and Ramp 1968). Steam-powered dredges replaced placer methods in northeastern Oregon during 1910 to 1920, greatly increasing gold production and stream bed disturbances. The Sumpter dredge mined over 10 miles of stream on the Powder River below Sumpter. Other tributary streams in the Powder River drainage were also dredged (Brooks and Ramp 1968).

Dredge mining had devastating effects on salmon and steelhead habitat. The method alters the existing stream bed totally and destroys riparian vegetation, leaving the stream channel unsuitable for fish. In addition to total stream bed disruption, large amounts of sediment are released and flushed downstream. In the Powder, this sediment settled out on gravel bars that fish used for spawning and feeding.

Besides these direct instream impacts, water diversion dams without passage facilities completely blocked anadromous fish runs and precluded use of upstream spawning areas. For example, Swan Falls Dam was built on the Snake River in 1910 to supply electricity for the mining districts of the Owyhee Mountains.

5.5.2 Reducing the Adverse Effects of Mining

Since passage of the federal Clean Water Act, both state and federal agencies have enforcement power to control mine discharges, gravel operations, and other water quality degradation. Each state in the Columbia River Basin has passed laws that are designed to improve and protect water quality and fish resources. For example, Idaho passed a Stream Protection Act (Idaho Code 42-3801) in 1971. Similarly, Oregon has passed the Waterways Act (ORS 390.805, et seq.), and Washington has passed the Fisheries Hydraulics and Environmental Protection acts (RCWA 43.21C, et seq.). All these laws represent important legislation regulating stream corridor use. However, lack of uniform enforcement, particularly in regulating sand and gravel operations (Thompson 1976b) has resulted in continuing degradation of fish habitat.

5.5.3 The Current Status of Mining Impacts on Fish

Present day mining activities on or near streams have relatively minor detrimental impacts on salmon and steelhead fish in the Columbia River Basin. Most historical detrimental effects (heavy metals, acid discharges, dredging, sedimentation) have been brought under control. However, some areas, such as Panther Creek, the upper South Fork Clearwater, and Bear Valley Creek in Idaho, still exhibit degraded habitat caused by earlier mining.

5.6 GRAZING

5.6.1 Overview

Over 50 percent of the Columbia River Basin is considered suitable for livestock grazing (mainly cattle and sheep) and more than half of this amount is currently in public lands managed by the Bureau of Land Management (BLM) and U.S. Forest Service (USFS) (Thompson 1976b). The use of large parcels of land for livestock grazing did not occur until after white settlers arrived in the mid-1800s, but from the start livestock owners tended to overstock the available ranges with their herds. Rangeland deteriorated as overgrazing caused "shallow-rooted" less nutritious plant species to replace high quality, deep-rooted species. Soil compaction and riparian damage also occurred as a consequence of overgrazing. These practices and resultant damage have occurred throughout most of the available rangelands.

Because of the various effects of uncontrolled grazing noted above, the land has become highly vulnerable to accelerated soil erosion which affects water quality and quantity in streams. According to Platts (1981), watersheds subject to intensive grazing experience increases in peak runoff and sedimentation as well as decreases in groundwater infiltration and minimum flows. Overgrazing on rangelands in the Columbia River Basin has had a detrimental effect on the Columbia River salmon and steelhead trout, primarily through sedimentation of spawning beds (Platts 1981). Studies that compared grazed and ungrazed watersheds have demonstrated considerable differences in fish productivity. For example, fish production in ungrazed streams ranged from 2.4 to 5 times greater than grazed streams (Platts 1981).

An indication of the amount of grazing that is occurring is the animal unit month (AUM). AUM is defined as the amount of forage necessary to completely sustain one animal unit (for example, one cow and her calf) for one month; or, as a unit of measurement of grazing privilege within grazing districts for one month. Figures 31 and 32 shows trends in animal unit months (AUMs) for Idaho and Oregon/Washington for 1945 to 1983. The AUM data indicate that grazing for the three-state area peaked during the mid-1950s and then decreased. In Oregon, grazing significantly increased during the early 1980s.

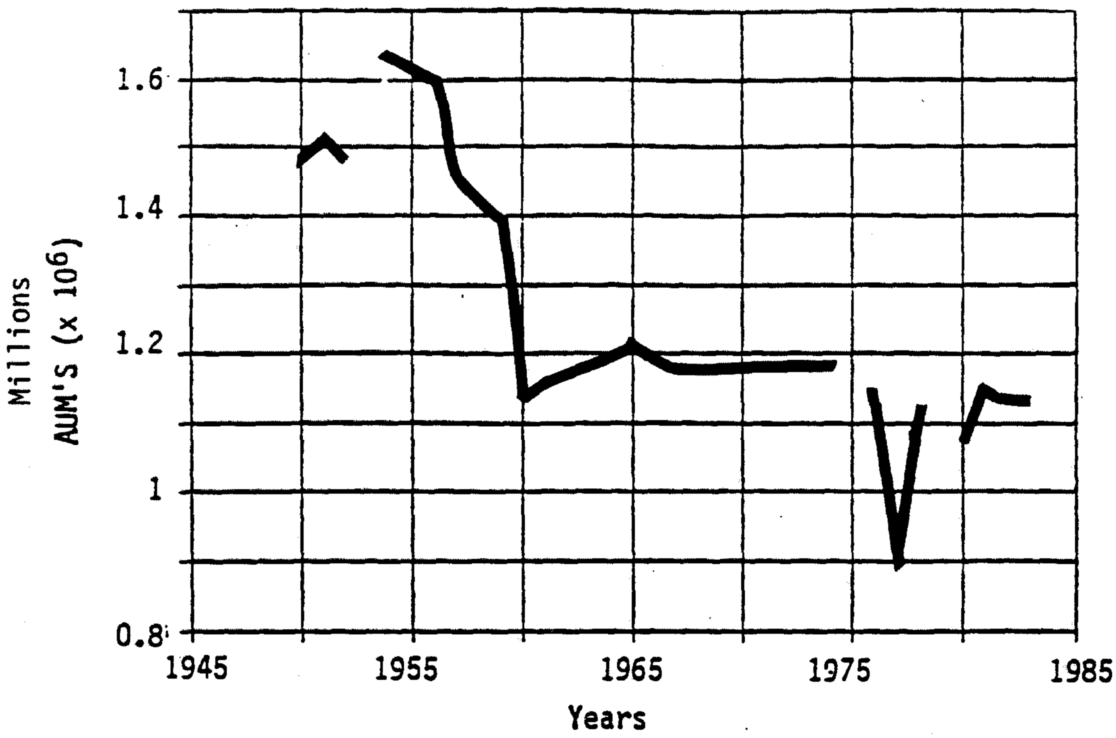


Figure 31. Grazing intensity in Idaho in AUM's from 1945-1983 (BLM, Public Land Statistics 1945-1983). (Discontinuous curves reflect data gaps.)

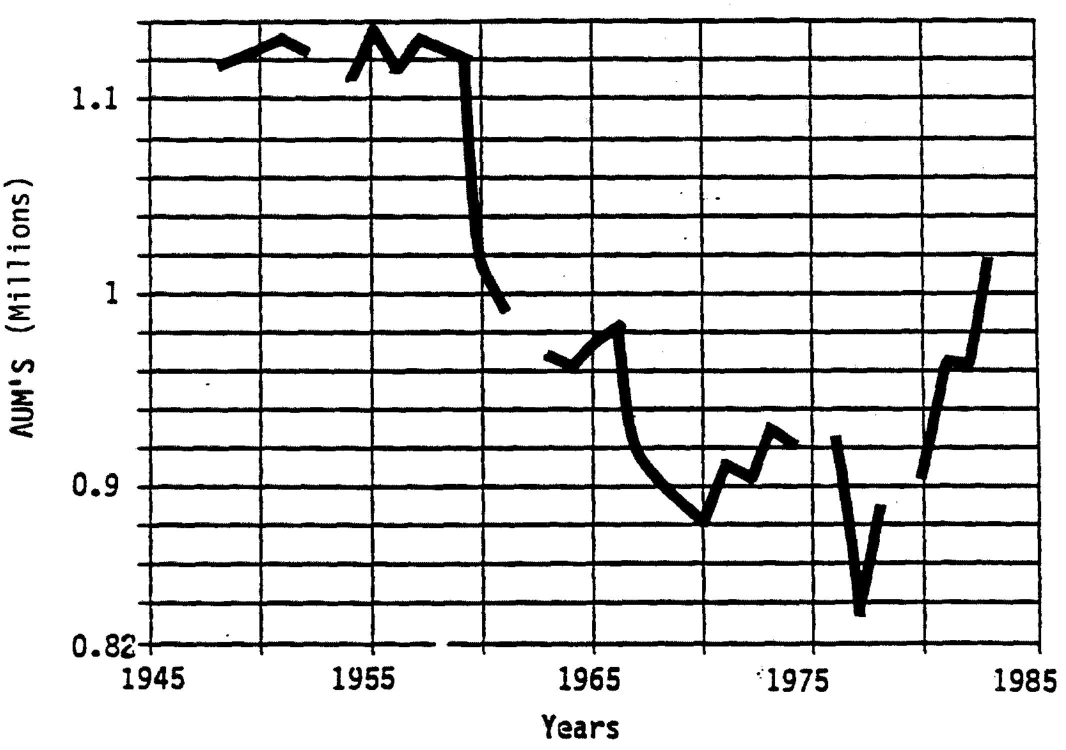


Figure 32. Grazing intensity in Oregon and eastern Washington from 1945-1983 (BLM, Public Land Statistics 1945-1983). (Discontinuous curves reflect data gaps.)

5.6.2 Reducing the Adverse Effects of Grazing

The first federal attempt to regulate grazing practices occurred in 1934 when the Taylor Grazing Act (43 U.S.C. 315, et seq.) was passed by Congress. The purpose of the act was to protect and to develop an orderly use of these lands. The Act had little immediate positive benefit because past practices were not easily changed. It was not until the mid-1960s that provisions of the Act for management by allotment was practiced extensively. Allotment management limits grazing to a specific number of AUMs per area of land as opposed to open range available to anybody's livestock.

Most of the mitigative actions affecting grazing are a result of range management practices by the USFS and BLM. In comparison to other developments, however, considerably less mitigation has been implemented to minimize impacts of grazing. Some measures used to achieve range rehabilitation and soil stabilization include increased control of livestock grazing through scientific range management practices, fencing, revegetation, and expanded fire protection (Pacific Northwest River Basins Commission 1971).

5.6.3 The Current Status of Grazing Impacts on Fish

The need for protecting streamside (riparian) habitat from livestock grazing continues to be a fisheries habitat management issue (Thompson 1976b). The most detrimental effects of grazing occur in late summer and early fall when low flows cause livestock to congregate near streams. These congregations cause stream bank deterioration, water pollution, and riparian habitat damage. It should be noted that through the use of current grazing technology and knowledge, and enforcement of pertinent laws, these problems could be solved.

5.7 AGRICULTURE/IRRIGATION

5.7.1 Overview

There are over 25 million acres of farmland in the Columbia River Basin -- 12 percent of all land in the basin. Major crop-producing areas are located in central Washington and southern Idaho (Thompson 1976b).

Figures 33 through 37 show the number of acres in farms from 1900 to 1982 in four areas of the Columbia River Basin. The two lower Columbia River areas and the two Snake River areas analyses have been combined due to difficulties in separating data for these areas.

In general, land used for farming in the Columbia River Basin increased steadily until about 1960 and leveled off. There are two exceptions to this trend. In the Columbia River above Chief Joseph Dam, farming increased between 1925 and 1932, followed by a substantial decrease in farms in 1935. In the Willamette River drainage, land in farms decreased dramatically after 1950.

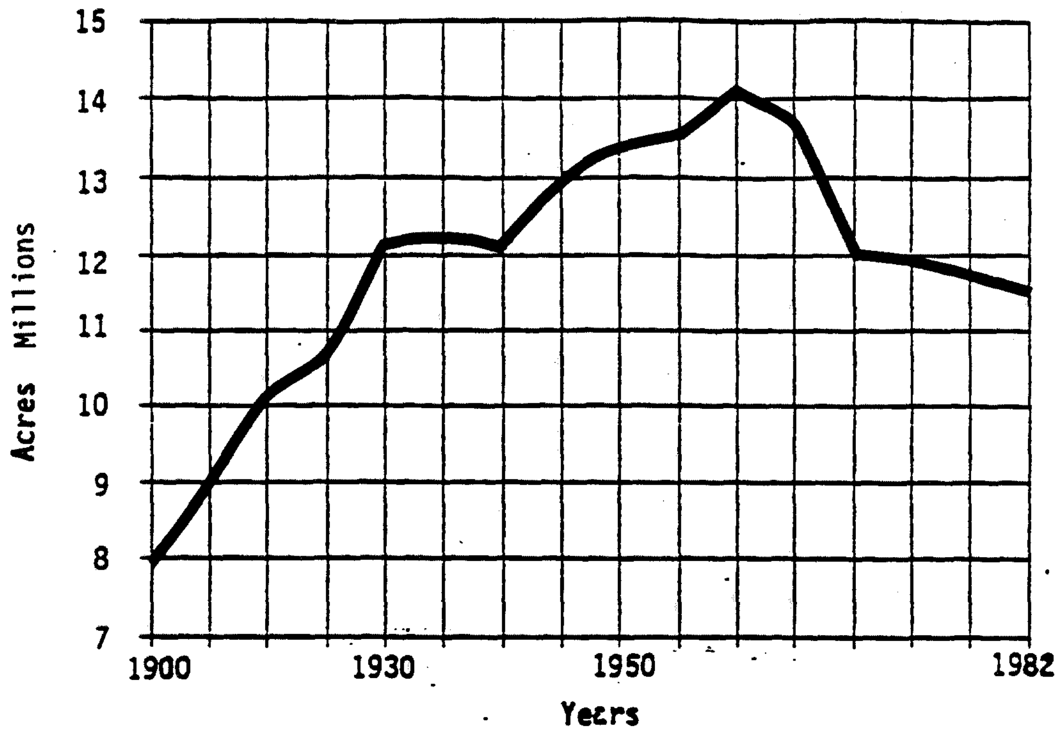


Figure 33. Acres in farm land for the lower Columbia area (U.S. Department of Commerce, 1900-1982a).

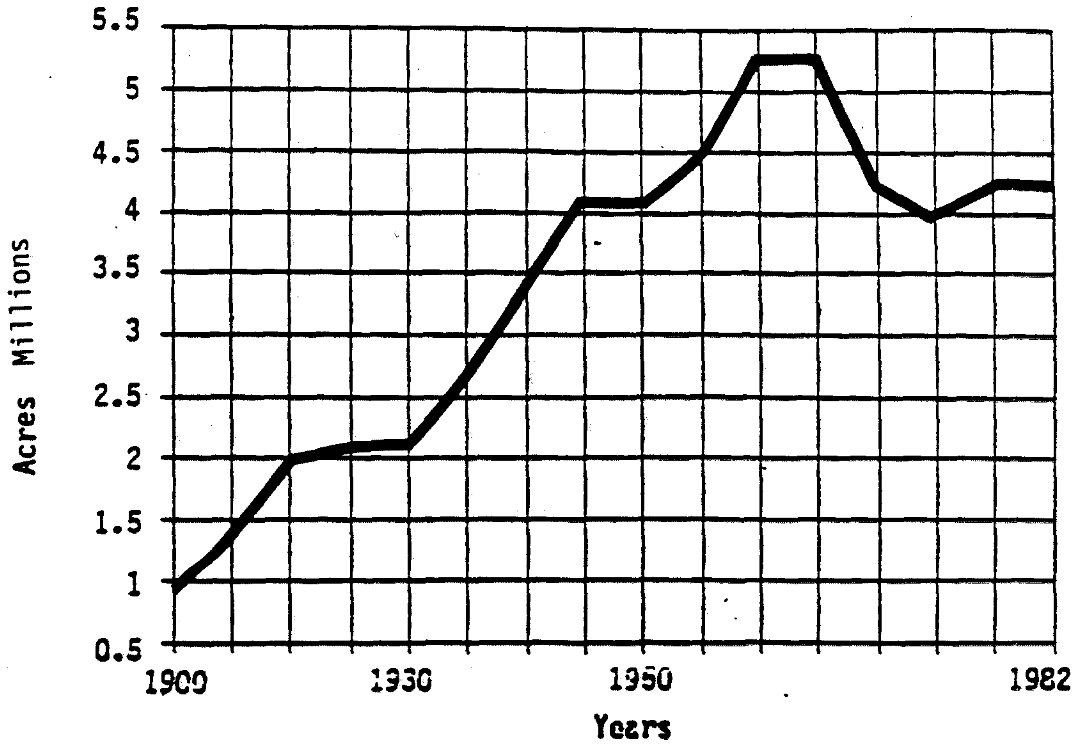


Figure 34. Acres in farm land for the middle Columbia River area (U.S. Department of Commerce 1900-1982a).

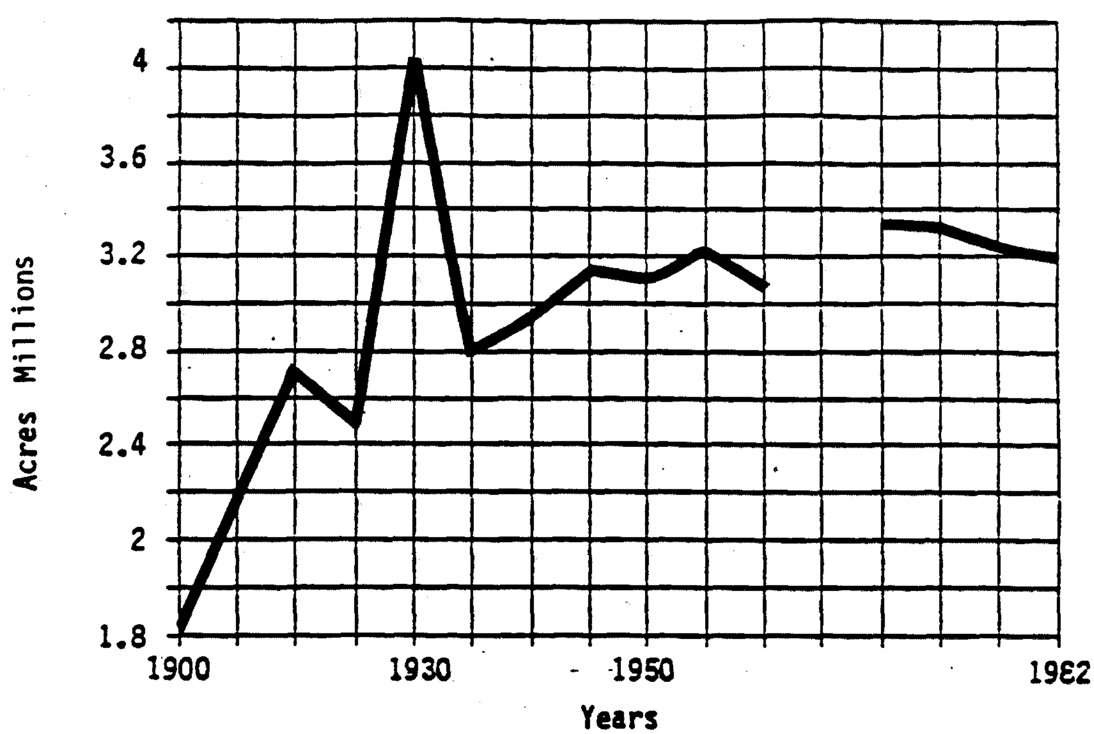


Figure 35. Acres in farm land for the upper Columbia River area (U.S. Department of Commerce 1900-1982a).

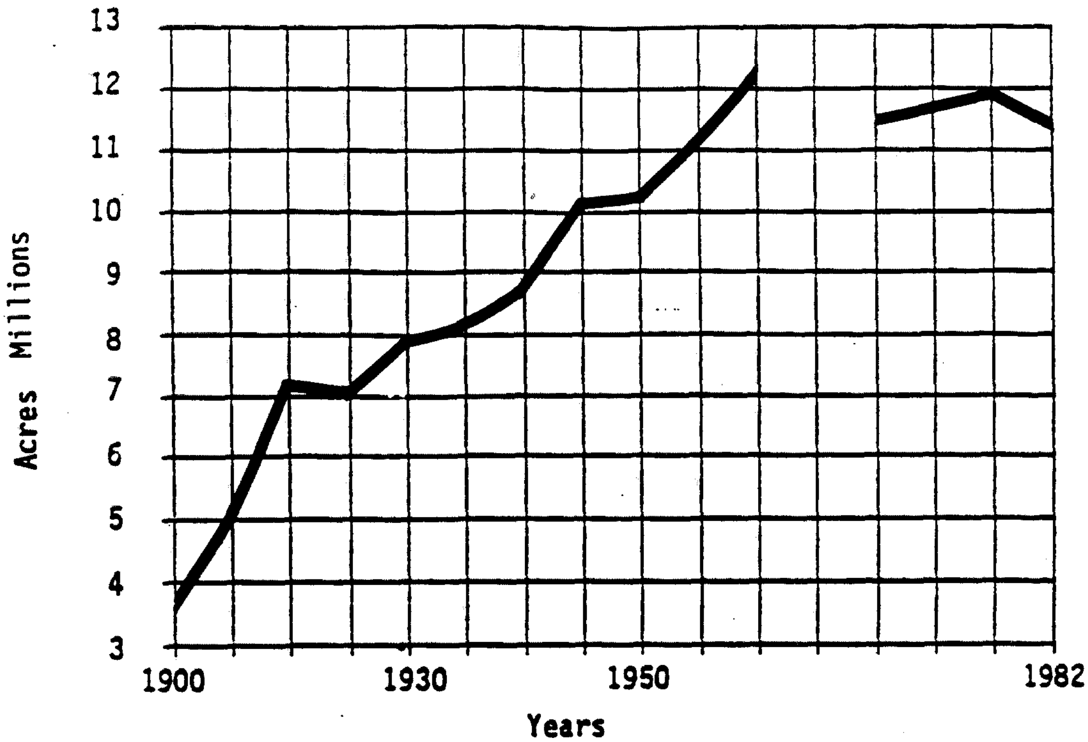


Figure 36. Acres in farm land for Snake River area (U.S. Department of Commerce 1900-1982a). (Discontinuous curve reflects data gaps.)

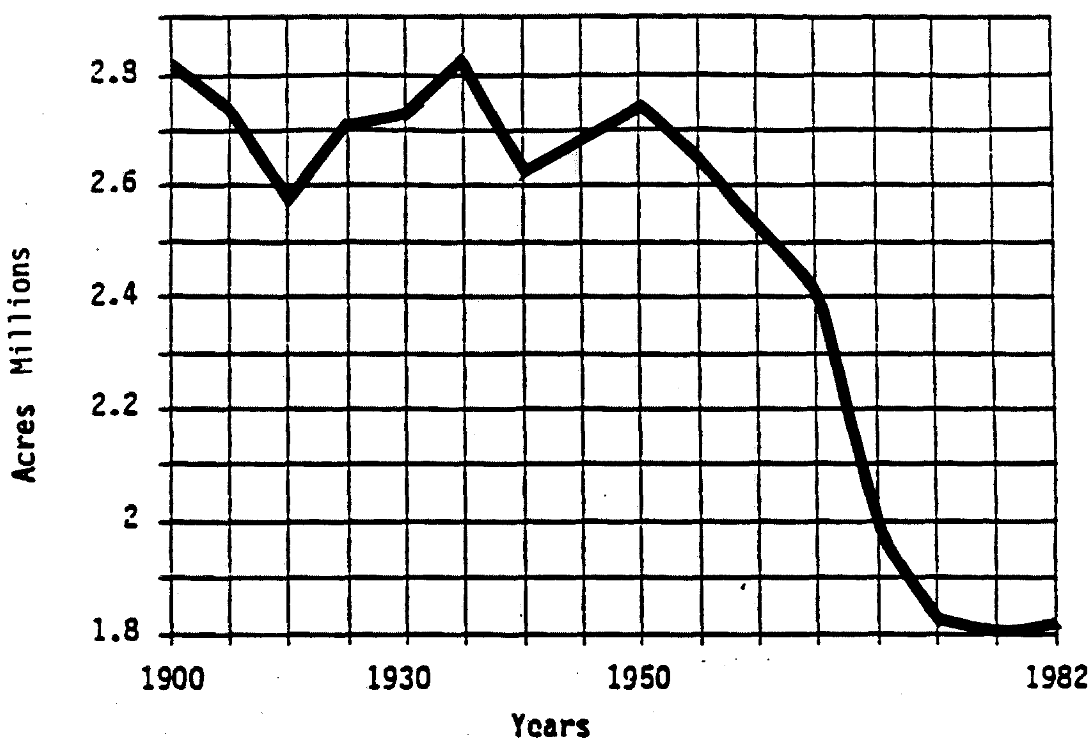


Figure 37. Acres in farm land for the Willamette River drainage (U.S. Department of Commerce 1900-1982a).

A history of farming in the basin can be seen through the development of irrigation. Irrigation in the Columbia River Basin developed slowly after settlers arrived in the 1800s. The first known irrigation in the basin was recorded prior to 1840 at missions near Walla Walla, Washington, and Lewiston, Idaho (Columbia River Water Management Group 1983). The first irrigation project in the Columbia River Basin was started in the Walla Walla River Valley in 1859 (Craig and Hacker 1940). Subsequently, water projects were developed in the John Day, Umatilla, and Hood River valleys in the 1860s. By 1889 there were 400,000 acres under irrigation in the Columbia River Basin (Pacific Northwest River Basins Commission 1971).

Several factors contributed to the increased interest in irrigation in the 1890s and early 1900s. An expanding market for foodstuffs and the completion of railroads attracted commercial-scale farmers to the basin during the late 1800s. Two Congressional acts, the Oregon Donation Land Law (Act of Sept. 27, 1850, 9 Stat. 496) and the Homestead Act of 1862 (Act of May 20, 1862, 12 Stat. 392), also created a demand for land. Legislation promoting irrigation development by private enterprise also passed during this period. The 1877 Desert Land Act (43 U.S.C. § § 321-329) allowed the sale of lands in 640-acre parcels, provided the land was irrigated for three years. Although less successful, the Carey Act of 1894 (43 U.S.C. § § 641-648) encouraged irrigation development by granting individuals 160 acres. In 1902, the Reclamation Act (32 Stat. 388) authorized the federal government to assist in irrigation development and enabled settlers to own 160 acres for the purpose of irrigating crops.

The effect of this legislation was to increase irrigated lands in the basin -- from 0.5 million acres in 1900 to 2.3 million acres in 1910. Total irrigated acres increased to 2.9 million in 1925, 6.6 million in 1966, and 7.6 million in 1980 (Columbia River Water Management Group 1983). Today irrigated lands are increasing at about 53,000 acres per year with a projected area of about 10.5 million acres by 2030 (Dillard 1985).

The funding for the various irrigation projects in the Columbia River Basin has varied considerably, depending upon the area. Overall, more than 70 percent of the irrigation development in the basin was initiated by individuals, cooperatives, and agencies other than the federal government.

However, most of the projects have received some federal support for obtaining supplemental water for developing dry lands (Pacific Northwest River Basins Commission 1971).

Irrigation methods have evolved from the initial concept of simple stream diversions to complex systems that use a variety of pumping and application mechanisms such as sprinklers, storage reservoirs, groundwater pumps and pressure distribution devices (Pacific Northwest River Basins Commission 1971). The early irrigation systems, which consisted mainly of gravity systems, were privately designed, financed, and built (Markham 1975). Many of the early irrigation projects also used a pump with a single intake line to feed the gravity system. The pumping/intake systems developed during the early and mid-1900s included vault-like structures with rectangular screened openings, pier-like structures supporting turbine pumps, and combination pier/vault structures (Swan et al 1980). Beginning in the 1920s, ditches or canals were often constructed to route water to pump stations (Easterbrook 1985).

The rapid increase in irrigation during the early 1900s was due to a decline in private development and an increase in federal multipurpose projects, primarily through the Bureau of Reclamation (Markham 1975). Beginning with the initiation of the Bonneville Dam in 1933, the Corps of Engineers also became involved with dam projects. Most of the major federal storage projects are multipurpose, which includes authorization for irrigation.

The number of individual intake systems for irrigation in the Columbia River Basin was extremely large by the mid-1900s. Mallett (1970) identified over 700 intake structures in Oregon and Idaho. The estimated number of intake structures during peak operation in Washington was at least 200 (Easterbrook 1985).

Although acres of land irrigated is the most common unit used to describe irrigation development, its use in characterizing historical trends should be clarified. The acreage irrigated does not reflect changes in irrigation practices that resulted in more efficient use of water. In other words, sprinkler systems need less water to irrigate the same area of land than is required for gravity feed systems. The dominance of sprinkler irrigation generally began in the mid-1960s.

To account for changes in irrigation practices, it is also useful to examine the amount of water diverted for irrigation (acre-feet). Federal records for 1947 to 1983 show the volume of water diverted to farms increased from about 2.6 million acre-feet in 1947 to 12.2 million acre-feet in 1969 (Table 27). Since 1969, the amount of water diverted by federal projects for irrigation has ranged between about 9.5 and 12 million acre-feet. This leveling off of federal irrigation water use is due to the efficiency of sprinkler systems and the involvement of non-federal projects. The amount of additional water diverted by non-federal projects is not readily available in the literature.

All portions of the Columbia River Basin have some irrigated land, but significant concentrations occur near large irrigation projects (Columbia River Water Management Group 1983). These areas include the Snake River plain from the Wyoming-Idaho state line to the Idaho-Oregon state line; the Yakima Valley and east of the Columbia River from Moses Lake on the north to the mouth of the Snake River on the south in Washington; and the Deschutes, Willamette, and Crooked river basins in Oregon. Below, a more detailed discussion of the location of irrigated land is provided for the four major areas of the basin.

The following sections describe irrigation development and related impacts to salmon and steelhead resources in the six areas of the Columbia River Basin. The two lower Columbia River areas and the two Snake River areas analyses have been combined due to difficulties in separating data for these areas.

5.7.1.1 Lower Columbia River Area

Non-Indian irrigation in the lower Columbia River area began in 1845 around Walla Walla, Washington (Pacific Northwest River Basins Commission 1971). Development proceeded gradually, reaching nearly 300,000 acres of irrigated land in the 1920s. As shown in Figure 38, development leveled off from 1925 to about 1950. During this period, four areas (Umatilla

Table 27 - Acre-feet (x 1,000) of surface water delivered to farms in the Columbia River Basin by the Bureau of Reclamation.

Year	Upper[1] Columbia	Middle[2] Columbia	Lower[3] Columbia	Snake	Total
1947	0	782.2	397.9	1,459.0	2,639.1
1951	32.8	845.8	446.7	1,632.7	2,958.0
1953	20.4	860.3	340.0	2,128.4	3,349.1
1955	6.2	885.5	509.5	1,719.0	3,120.2
1957	<10.0	1,668.9	444.2	2,150.6	4,273.7
1959	12.3	1,977.8	336.7	2,450.9	4,777.7
1961	13.2	2,294.2	351.2	2,107.4	4,766.0
1963[4]	---	---	---	---	---
1965	45.2	2,764.2	432.6	2,370.3	5,612.3
1967	79.3	---	706.3	7,599.9	8,385.5
1969	177.6	3,468.8	699.3	7,893.4	12,239.1
1971	235.7	3,392.0	627.1	6,440.0	10,694.8
1973	266.3	3,672.0	712.0	6,287.0	10,937.3
1975	266.0	3,513.4	741.5	6,078.3	10,599.2
1977	258.3	3,006.6	658.8	5,963.3	9,887.0
1979	214.9	4,847.6	664.5	5,926.0	11,653.0
1981	216.8	3,737.0	718.4	6,051.0	10,723.2
1983	135.6	3,829.0	608.4	5,151.8	9,724.8

Source: Bureau of Reclamation (1947 through 1983).

-- = Data not available (assumed to be approximately 3,000 acre-feet).

[1]Columbia Basin above Chief Joseph Dam.

[2]Columbia Basin between the confluence with the Snake River and Chief Joseph Dam.

[3]Columbia Basin below the confluence with the Snake River.

[4]Data not available for 1963.

River/Willow Creek, John Day River Basin, Kennewick Return Flow, and Deschutes Project) contained most of the irrigated land (Table 28). Beginning in the 1950s, irrigation expanded substantially to about 850,000 acres of land in 1980. Two areas showing the largest growth during this period were the Willamette Basin and the Deschutes Project. Although the Willamette Basin is presently the dominant irrigation area, its development was slow until the 1930s.

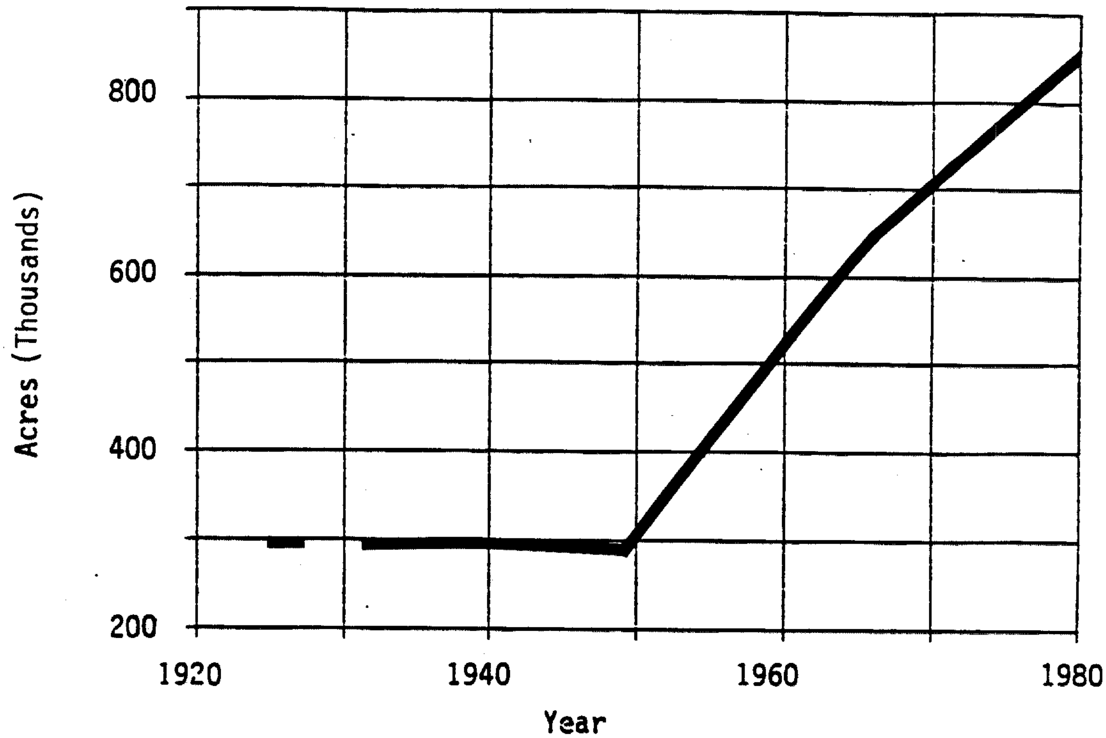


Figure 38. Total acres irrigated in the lower Columbia River area (Columbia River Water Management Group 1983).

The total estimated storage capacity for irrigation dams in the lower Columbia River area is 315,240 acre feet. Drainages that store the most water include the Deschutes, Tualatin, and Willamette. A review of the individual storage capacities of irrigation dams, found in Appendix C, Table C-1, indicates that volumes are relatively small (less than 300 acre feet) except in the Deschutes, Tualatin, and Willamette drainages.

Irrigation development in the lower Columbia River is characterized by sizable concentrations of irrigated land resulting from large project development. Some projects were funded by the federal government. Bureau of Reclamation records (1947-1983), show the volume of water diverted from federal projects has ranged from approximately 450,000 acre-feet in 1947 to

Table 28 - Acres of land irrigated (x 1,000) in the Columbia River Basin.[1,7]

	1925	1928	1948/50	1966	1980
Lower Columbia[2]					
Walla Walla River	26.2	25.8	35.6	48.2	75.4
Umatilla River/Willow Creek	50.2	50.6	52.6	46.0	37.9
John Day River Basin	45.3	47.1	50.3	56.4	57.8
Kennewick Return Flow	50.2	50.6	52.6	46.0	37.9
Pumping from McNary to North Side	3.2	3.2	3.2	4.1	34.1
Pumping from McNary to Umatilla Area	0	0	--	8.1	37.8
Willamette Basin	3.9	4.0	54.6	14.25	219.5
Fern Ridge	0	0	1.0	1.4	1.5
Deschutes Project	75.5	75.0	0	235.1	190.5
Pumping from John Day Pool to Morrow and Gilliam Counties, Oregon	0	0	0	0	74.0
Deschutes River Basin, White River-Wapenita Project	5.5	5.5	--	13.9	17.0
Klickitat Basin	7.2	7.2	7.8	7.7	9.2
White Salmon River Basin	4.8	4.8	4.8	5.1	5.3
Hood River Basin	25.2	25.2	30.0	36.9	35.0
Klickitat-White Salmon	0	0	0	0	3.3
Total Lower Columbia[3]	297.2	299.0	292.5	523.15	836.2

-- = Information not available.

[1]Source: Columbia River Water Management Group (1983).

[2]Columbia River Basin below the confluence with the Snake River.

[3]Acreages not available for the Lewis and Cowlitz Rivers.

[7]Increase or decrease in numbers of acres irrigated does not necessarily reflect amount of water used.

Table 28 (cont)

Middle Columbia[4]	1925	1928	1948/50	1966	1980
Kettle	4.5	4.6	5.8	10.7	21.1
Okanogan	84.0	80.4	93.6	117.1	133.7
Ferry-Stevens	5.7	5.7	10.0	21.0	21.7
Methow-Okanogan	32.0	31.3	35.0	34.5	39.4
Chelan-Entiat	6.1	7.2	7.2	6.5	6.5
West of Banks Lake	5.8	5.4	15.8	23.4	30.0
Wenatchee	24.6	24.6	25.0	26.0	26.0
Yakima	335.0	333.1	--	505.0	580.5
Columbia Basin Project	0	0	5.8	493.3	534.0
Big Bend	5.8	5.9	70.0	118.3	276.4
Total Middle Columbia[5]	503.5	498.2	268.2[3]	1,355.8	1,669.3
Upper Columbia[6]					
Upper Columbia above Mica	4.6	4.7	6.4	8.6	11.8
Mica to Keenleyside	0.7	0.7	1.0	1.3	2.1
East Kootenay	1.8	1.8	4.0	6.3	11.9
West Kootenay	1.8	1.8	4.0	6.3	11.9
Slacan Basin	0.5	0.5	0.9	1.2	3.8
Kneeleyside to Pend Oreille	0.3	0.3	0.5	0.8	0.9

[4]Columbia Basin between the confluence with the Snake River and Chief Joseph Dam.

[5]Total does not include Yakima Basin (not reported in 1948).

[6]Columbia Basin above Chief Joseph Dam.

Table 28 (cont)

	1925	1928	1948/50	1966	1980
Upper Clark Fork	125.8	125.0	128.0	131.0	131.0
Bitterroot	111.0	108.0	108.0	106.0	118.6
Upper Flathead	6.2	6.0	8.5	26.1	30.4
Pend Oreille	3.7	3.8	5.9	7.6	9.3
Flathead Irrigation District	31.8	33.8	93.8	116.9	126.2
Lower Clark Fork	15.3	15.5	20.0	27.0	20.9
Spokane	25.3	24.6	25.0	42.0	55.4
Total Upper Columbia	319.1	316.7	389.2	456.6	491.8
Snake River					
Lower Snake					
Upper Salmon	83.5	84.3	107.4	122.4	121.0
Lower Salmon	15.8	16.8	16.6	16.6	17.6
Grande Ronde	90.7	92.1	96.5	97.0	87.7
Clearwater	3.6	3.4	3.5	3.0	2.4
Palouse-Lower Snake	27.6	26.6	26.6	26.0	56.2
Middle and Upper Snake	1,528.4	--	--	3,818.4	4,296.9
Total Snake River Basin	1,749.6	--	--	4,083.4	4,581.8
TOTAL COLUMBIA RIVER BASIN	2,881.9	--	--	6,578.1	7,601.2

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740,000 acre-feet in 1975 (Figure 39). Based on statistics available for 1966, the federal projects represented about 33 percent of the total water diverted. The Umatilla, Walla Walla, John Day, Deschutes, and Hood River basins collectively diverted about 2.3 million acre-feet; the Willamette River diverted 569,000 acre-feet (Pacific Northwest River Basins Commission 1971). Diversions in these two areas represented annual depletions of about 1 million and 0.2 million acre-feet, respectively.

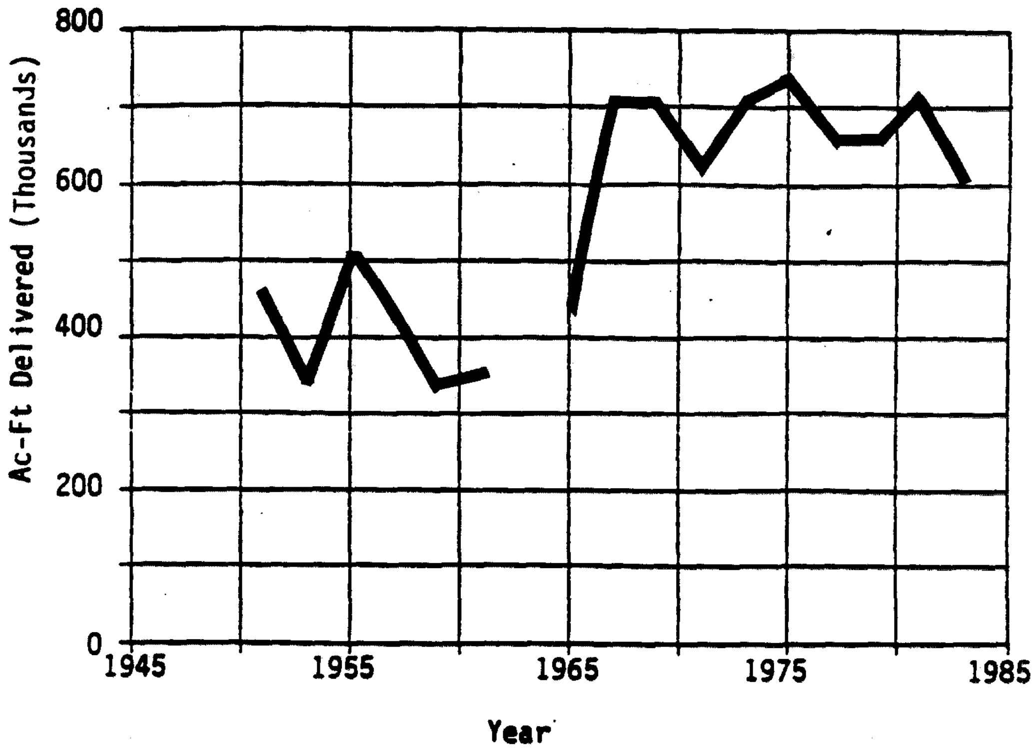

Figure 39. Total irrigation water diverted (acre-feet) by federal projects in the lower Columbia River area (BOR 1947-1983). (Discontinuous curve reflects data gaps.)

Irrigation development has been identified as the primary cause or a major contributor in reducing salmon and steelhead runs in lower Columbia River tributaries (Fulton 1968; 1970). The losses are due to unscreened diversions and relatively low flows during the summer. Major rivers known to be affected by irrigation in the lower Columbia River area include the Deschutes, Hood, John Day, McKenzie, Santiam, Touchet, Umatilla, and Walla Walla (Fulton 1968; 1970). Stober et al. (1979) also concluded that anadromous runs were almost eliminated throughout the Umatilla due to irrigation withdrawals and concomitant low flows. Of these eight drainages, the Touchet, Umatilla, and Walla Walla rivers were identified as being affected solely by irrigation withdrawals. Primary species affected in these three drainages were spring chinook and steelhead in the Umatilla, spring chinook in the Touchet, and steelhead in the Walla Walla. All of these drainages are located in areas that exhibited considerable irrigation development in the early to mid-1900s, a period when unscreened diversions were common. Fish habitat in the lower mainstem portion of the Columbia River probably has been affected by water diversions in the middle and upper portions of the basin. However, it is not possible to quantify these effects in terms of numbers of fish lost.

5.7.1.2 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

Irrigation development in this area has consistently ranked second highest of the four areas. The first efforts occurred in the 1840s in the Yakima drainage and the 1850s in the Chelan-Okanogan area (Pacific Northwest River Basins Commission 1971).

Development proceeded rapidly after 1870 to 0.5 million acres irrigated in 1925 (Figure 40). Development leveled off until the 1950s, when rapid expansion occurred again. An important aspect of irrigation development in this area was that federal funding has supported a major part of the projects. The increase in the last 20 years is largely attributed to the Columbia Basin Project. The volume of water provided by federal projects has increased from about 1 million acre-feet in 1955 to 4.8 million acre-feet in 1979 (Figure 41). In 1966, a total of about 5.5 million acre-feet was diverted (Pacific Northwest River Basins Commission 1971). Of this, federal projects accounted for annual depletions of 2.6 million acre-feet for the Ferry-Stevens, Chelan-Okanogan, and Big Bend areas and 1.1 million acre-feet for the Yakima area.

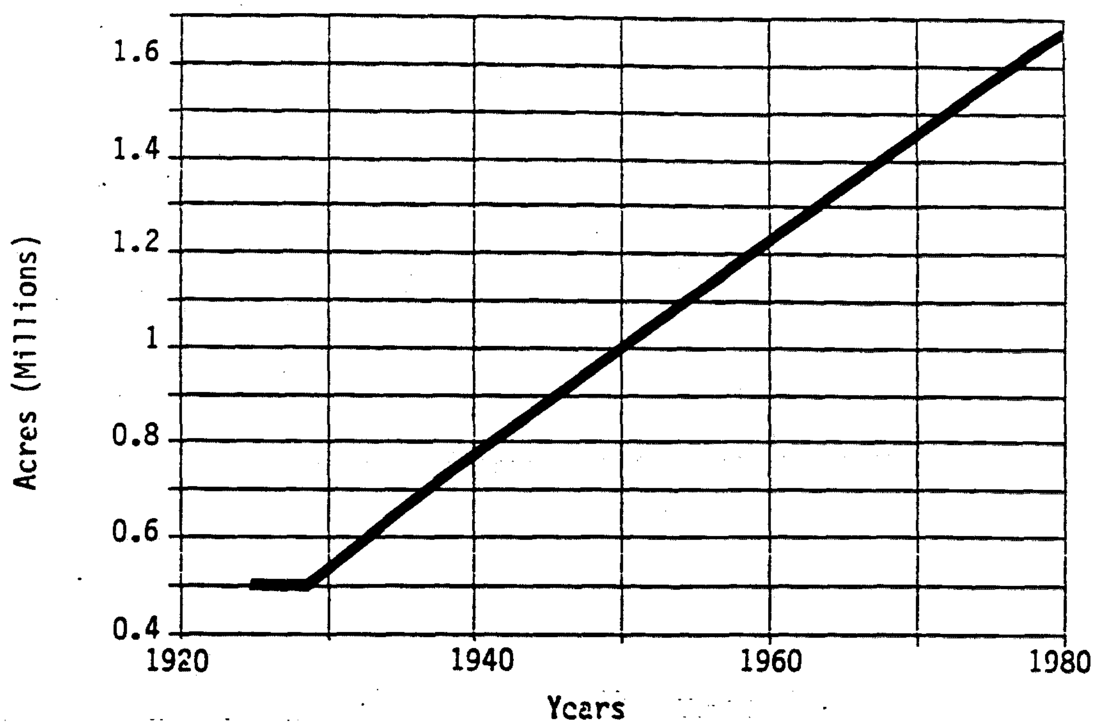

Figure 40. Total acres irrigated in the middle Columbia River area (Columbia River Water Management Group 1983).

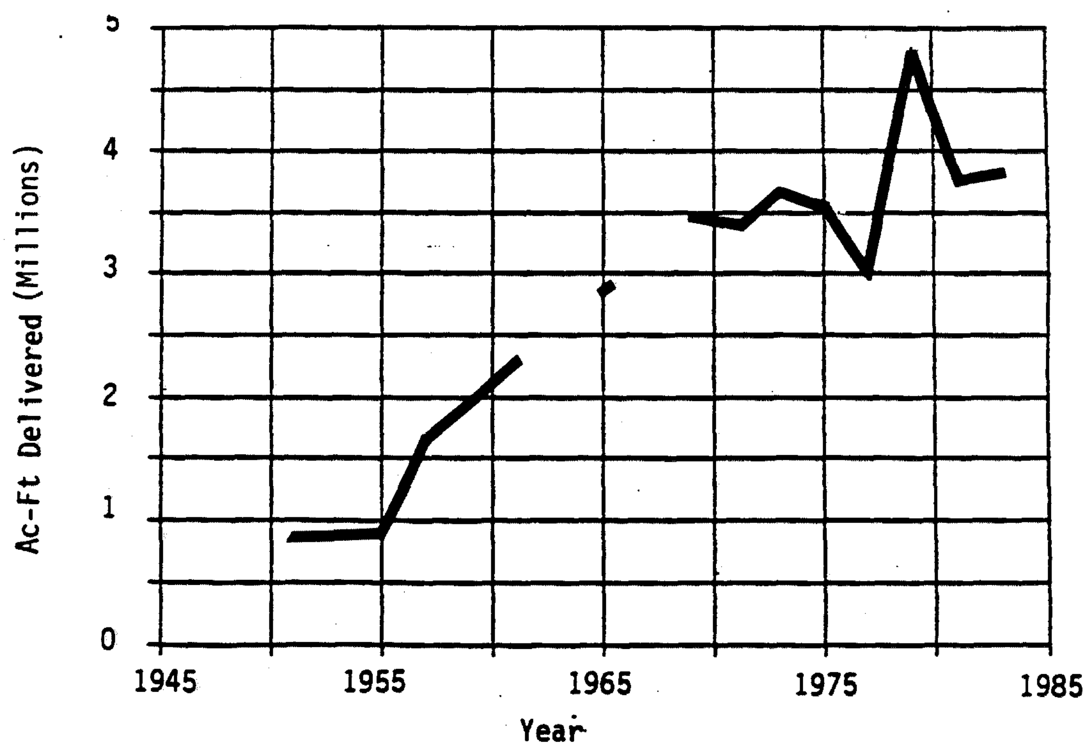

Figure 41. Total irrigation water diverted (acre-feet) by federal projects in the middle Columbia River area (BOR 1947-1983). (Discontinuous curve reflects data gaps.)

The predominant irrigation areas in this section are the Okanogan and Yakima, which have been important since the early 1920s (Table 28). The Columbia Basin Project, which provides water from mainstem pools, and the Big Bend area have become significant contributors since about 1960.

Most of the irrigation development in the middle Columbia area has been aided by multipurpose water projects. A total of 43 multipurpose dams in the middle Columbia area designate irrigation as a purpose. Multipurpose dams, by drainage, include 18 in tributaries of the Columbia River, seven in the Okanogan, seven in the Yakima, four in the Methow, four in the Wenatchee, and three in the Naches (Appendix C, Table C-1). Based on storage capacities, the largest projects include the North Dam (1,275,000 acre-feet) and O'Sullivan Dam (552,000 acre-feet) in the Columbia River drainage; and the Tieton Dam (203,500 acre-feet) and Cle Elum Dam (710,000 acre-feet) in the Yakima River drainage. A total of 12 dams, located in tributaries of the Columbia, Wenatchee, and Yakima Rivers (Tables 29, C-1), are exclusively for irrigation in the middle Columbia area. Except for several dams on the Columbia River tributaries, the storage capacity of these dams is small (less than 300 acre feet).

Salmon and steelhead resources have been affected by irrigation in the middle Columbia River. For example, in the Yakima River, predevelopment runs of about 600,000 salmon were drastically reduced from 1890 to 1905, which coincided with intense irrigation development (Davidson 1953; Stober et al. 1979). Dams, unscreened diversions, low flows, and high temperatures have contributed to the reductions primarily of spring chinook and steelhead. Other drainages affected by irrigation include the Methow and Wenatchee rivers (Fulton 1968; 1970). The Methow has been affected by irrigation withdrawals, while the Wenatchee was affected by unscreened irrigation diversions and low flows. Since 1970 when screening was completed at most sites in the middle Columbia area, problems with entrainment have decreased.

5.7.1.3 <u>Columbia River Above Chief Joseph Dam</u>

Irrigation development in this area began in the 1840s and 1850s at several locations in Montana. Development was slow and intermittent until the 1890s and 1900s, when completion of railroads spurred settlement. As a result of private and federally financed projects, irrigation has gradually

Table 29 - Total storage capacity of dams constructed exclusively for irrigation by major drainages in the Columbia River Basin.

	Storage Capacity Acre Feet		Storage Capacity Acre Feet	% Total
Lower Columbia[1]				
Columbia	190			
Crooked	6,310	Tualatin	54,738	
Deschutes	249,812	Umatilla	300	
Klickitat	15	Walla Walla	290	
Lewis	74	White	106	
Lukiamute	166	Willamette	2,286	
Santiam	91	Yamhill	862	
		TOTAL	315,240	29%
Middle Columbia[3]				
Columbia	27,120	Yakima	35	
Wenatchee	250			
		TOTAL	27,405	3%
Upper Columbia[4]				
Columbia	92			
		TOTAL	92	0%[5]
Snake River				
Big Wood	33,283	Owyhee	56,590	
Burnt	28,827	Payette	34,723	
Little Salmon	6,218	Powder	7,804	
Malheur	44,082	Salmon	308	
North Fork Payette	81	Snake	522,274	
		Weiser	3,954	68%
		TOTAL	738,144	
		BASINWIDE TOTAL:	1,080,881	100%

[1] See Table 20 regarding storage capacity of multipurpose and hydropower dams.

[2] Columbia Basin below the confluence with the Snake River.

[3] Columbia Basin between the confluence with the Snake River and Chief Joseph Dam.

[4] Columbia Basin above Chief Joseph Dam.

[5] 0.009%

increased in the upper Columbia River area since the early 1900s (Figure 42). Although federal irrigation projects have contributed to irrigation since 1911, the greatest contribution occurred from 1967 to 1971 (Figure 43). In 1966, federal projects provided about 40 percent of the estimated 2 million acre-feet diverted in the upper Columbia River area (Pacific Northwest River Basins Commission 1971). This federal share represented an annual diversion of 0.7 million acre-feet.

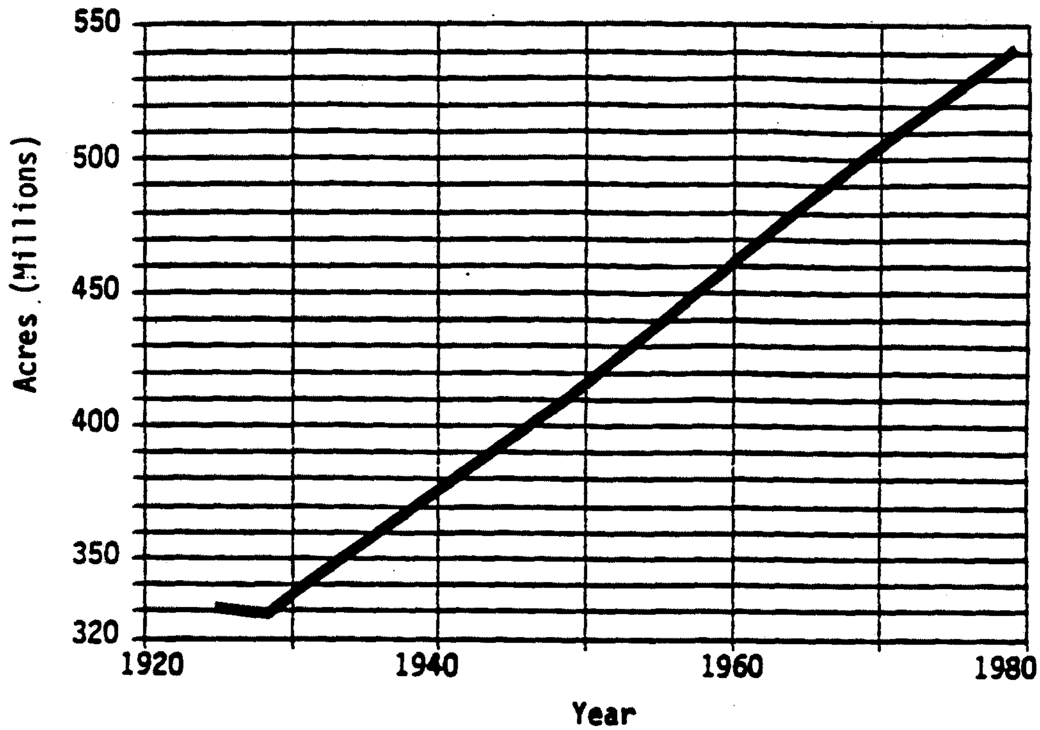

Figure 42. Total acres irrigated in the upper Columbia River area including some areas of Montana that were never used by salmon and steelhead (Columbia River Water Management Group 1983).

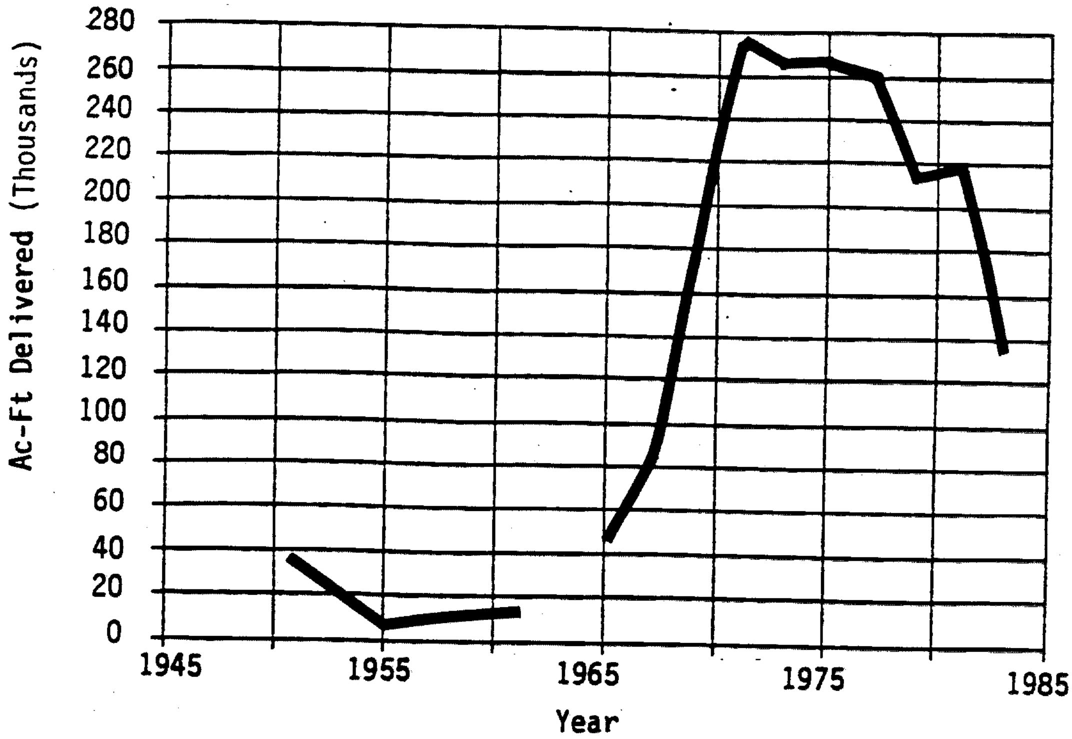

Figure 43. Total irrigation water diverted (acre-feet) by federal projects in the upper Columbia River area (BOR 1947-1983). (Discontinuous curve reflects data gaps.)

Multipurpose dam projects have provided most of the irrigation water in this area. Twelve multipurpose projects have specified irrigation as one of their several purposes. Of these, Grand Coulee Dam is the largest. Only one project has been constructed exclusively for irrigation in this area. The dominant irrigation areas in the upper Columbia River area include the upper Clark Fork, Bitterroot, and Flathead Irrigation District (Table 28); however, salmon and steelhead have never used these areas.

5.7.1.4 Snake River Area

Of the four Columbia River areas, the Snake River has continually ranked highest in amounts of land irrigated and water diverted. Irrigation development in the Snake River area began in the 1860s and grew rapidly due to private individuals and corporations (Pacific Northwest River Basins Commission 1971). Irrigated land in the Snake River area has increased from about 1.7 million acres in 1925 to 4.5 million acres in 1980 (Figure 44). The Boise Bureau of Reclamation Project of 1902 was the first federal irrigation project in the Snake River Basin. Although federal projects provided about 2 million acre-feet per year from 1947 to 1961, the largest contribution occurred after 1966 when volumes exceeded 7 million acre-feet annually (Figure 45). In 1966, the total amount of water diverted for irrigation in the Snake Basin was estimated at 21 million acre-feet (Pacific Northwest River Basin Commission 1971).

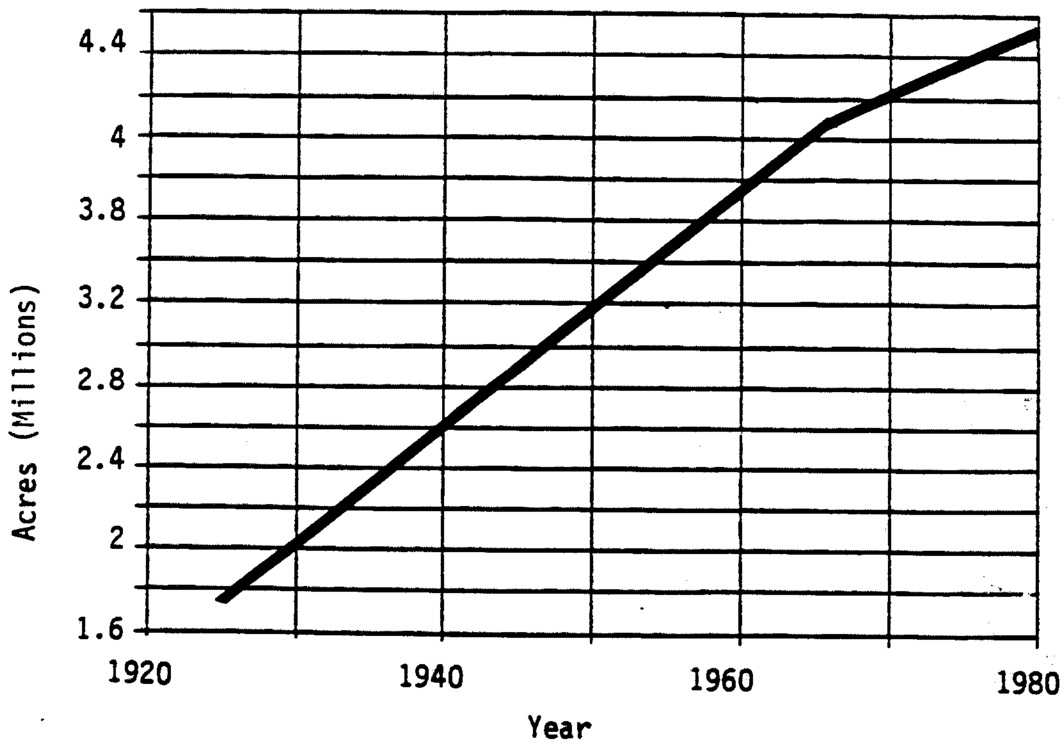

Figure 44. Total acres irrigated in the Snake River area (Columbia River Water Management Group 1983).

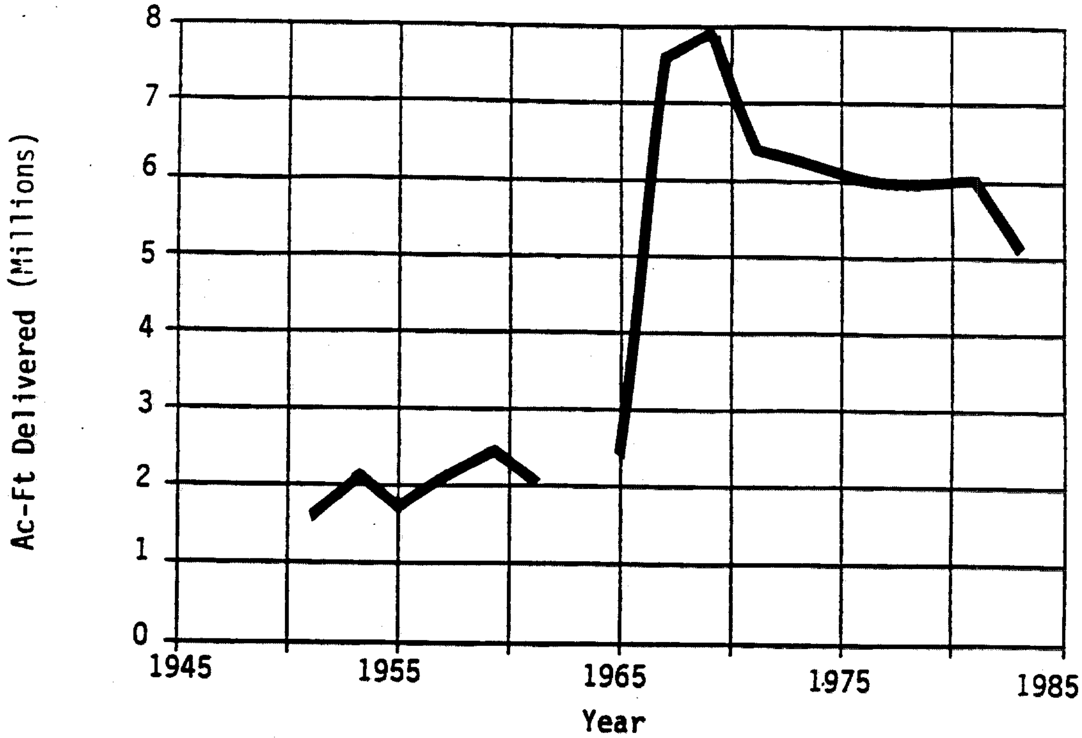

Figure 45. Total irrigation water diverted (acre-feet) by federal projects in the Snake River area (BOR 1947-1983). (Discontinuous curve reflects data gaps.)

The storage capacity of these dams is 738,144 acre-feet. In descending order, projects in the Snake, Owyhee, Malheur, Payette, Big Wood, and Burnt drainages store the largest quantities of water. A number of projects store over 20,000 acre-feet each. In addition to the irrigation dams, there are 37 multipurpose dams in the Snake River area (Appendix C, Table C-1). The majority of these dams are located in the Snake (13), Boise (5) and Payette (4) drainages. The largest storage capacity for the multipurpose dams include the Owyhee Dam (1,120,000 acre-feet) on the Owyhee River, Anderson (509,000 acre-feet) and Arrowrock dams (301,000 acre-feet) on the Boise River, and Cascade Dam (860,000 acre-feet) on the Payette River.

Although dams caused total elimination of fish runs in the Boise River, Burnt Creek, Pine Creek, and the Weiser River, irrigation withdrawals already had reduced the numbers of fish prior to dam construction. Anadromous fish losses in the remaining eight rivers were caused by a combination of several developments. Observations by Parkhurst (1950a, b, c) confirm diversion problems in many of the rivers listed above, as well as the Payette River. The Pacific Fishery Management Council (1985) also has identified irrigation diversions, in combination with dams or channelization, as reducing anadromous fish runs in the mainstem of the Snake River and Grande Ronde River. The most critical period for anadromous fish losses probably occurred during intensive irrigation development when diversions were unscreened (1880 to 1940s in Washington; 1880 to 1970s in Oregon and Idaho).

5.7.2 Impacts of Agriculture/Irrigation on Salmon and Steelhead

Agricultural practices have affected anadromous fish resources in the Columbia River Basin. The most severe impacts, not directly related to irrigation, are attributed to removal of stream corridor vegetation and channelization of streams. These practices have resulted in erosion, causing large amounts of sediment to flow into streams.

The impacts of irrigation activities on salmon and steelhead can be divided into four categories: 1) changes in water quality associated with return flows; 2) water level fluctuations and flow alterations due to diversions and dams; 3) obstruction to fish passage and loss of habitat due to dams; and 4) entrainment and impingement in intake systems (Stober et al. 1979).

Problems associated with return flows (irrigation water flowing off of irrigated fields back into streams) from irrigation include increases in temperature, sediment loads, phosphates and nitrates, pesticides, salinity, parasitic nematodes and coliform bacteria (Whitney and White 1984). The potential impacts on anadromous fish include temperature-caused effects on smolts, adult migration, and spawning; nematode infestations; direct toxicities (pesticides); habitat degradation (sediment); and alterations in nutrients and salinity. Although these problems exist throughout most of the Columbia River Basin, the most evident impacts are found in areas with concentrated irrigation efforts, such as the Yakima Valley and the lower mainstem sections of the Columbia River, where cumulative impacts of return flows are more pronounced (Whitney and White 1984).

Numerous problems have been associated with water level fluctuations and flow alterations due to water storage and withdrawals for irrigation. According to Stober et al. (1979), the major effects on anadromous fish include reduction in food sources; loss of important spawning, rearing, and adult habitat; increased susceptibility of juvenile salmonids to predation; delay in adult spawning migration; increased egg and alevin (fish that have hatched but not migrated out of the gravel) mortalities; stranding of fry; and delays in downstream migration. Except for food sources, all these impacts are related to the effects of flow alterations and water level fluctuations on the preferred depth, flow, substrate, temperature, and other habitat requirements for salmon and steelhead. Instream flow studies have shown that significant reductions in salmonid habitat have occurred on the mainstem Columbia during low water years (Karr 1982). Also, irrigation diversions often completely dry up or seriously dewater tributary streams in the upper basin, even in average water years (Chaney 1978).

Critical periods for salmon and steelhead include juvenile migration from April to June and adult spawning in the summer and fall. Water withdrawals during these periods can dewater eggs, trap pre-emergent fry, and strand young fish. Relatively higher water temperature during low flow combined with warm irrigation return flows also can inhibit salmon migrations, as observed in the Yakima, Okanogan, and Snake rivers (Stober et al. 1979). In addition, low water levels can concentrate fish, which makes them more susceptible to predation and disease.

Irrigation dams also represent temporary and permanent blockages to adult spawning migrations and smolt outmigration. See discussion in Section 4.3 on impacts of water storage projects on fish. As noted there, many storage projects are built and operated for irrigation purposes as well as for hydropower generation and other uses.

The impingement of juvenile salmon and steelhead on intake screens and entrainment into the intake systems also have contributed to fish losses due to irrigation. As water is withdrawn during the irrigation period (April to October), fish become stranded in the canals and eventually die. Based on surveys summarized by Corely (1963), fish losses in irrigation canals were large. The U.S. Bureau of Fisheries recovered 4,000 fish in irrigation canals on the Yakima River during one summer, which represented a potential loss of five million fish for the entire system. Similarly, the Oregon Fish Commission caught approximately 51,000 juvenile salmon in 14 different irrigation canals in 1956. An estimated 422,000 salmon fingerlings died in irrigation canals in the Lemhi River near Salmon, Idaho.

An important characteristic of the intake structures for irrigation was that no protective screens were used to direct fish until the 1930s in Washington and the 1960s and 1970s in Oregon and Idaho (National Marine Fisheries Service 1981; Easterbrook 1985). Assuming that irrigation began around 1890, this represents 40 to 60 years of unscreened diversions in Washington and 70 to 80 years in Oregon and Idaho.

However, the problem has not been eliminated, as shown in recent inspections of screens. Surveys on the Columbia River between McNary Dam and Lewiston, Idaho, revealed that 34 of 95 sites did not meet the federal criteria for intake velocities and/or screen mesh sizes (Swan 1981). Similar inspections at 205 intake sites between Bonneville Dam and Lewiston, Idaho, and between Priest Rapids and Wells Dam indicated that 24 sites had damaged screens or contained no screens at all (Swan et al. 1980). The installation of protective screens for irrigation intakes also has caused mortalities due to impingement (Swan et al. 1980), although there appear to be no studies quantifying losses.

5.7.3 Reducing the Adverse Effects of Agriculture/Irrigation

The adverse effect of farming could be controlled and probably eliminated through improved agricultural practices and enforcement of the laws designed to protect instream resources.

The installation of screens on intake structures is one measure used to compensate or minimize impacts due to irrigation. Most of the screens in Oregon and Idaho were installed using funds provided by the Mitchell Act, a multipurpose mitigation program described in Chapter 6. Most of the screens in Washington were installed with federal and state funds (Easterbrook 1985). Screens are maintained by the state and federal fish agencies. Although there are regulations concerning mesh size and approach intake velocities, screen inspections have identified problems in adhering to these requirements and in their enforcement (Swan et al. 1980).

The issue of protecting fish from flow depletion has been addressed only recently in the Columbia Basin (Thompson 1976b). Minimum stream flows in Washington have been established in the mainstem Columbia, Wenatchee, Methow, and Okanogan basins. The Oregon Water Policy Review Board has adopted minimum flows on over 300 streams throughout the state, but enforcement has not been strict. In Idaho, minimum flow requirements have been established in the mainstem Snake River and 12 tributaries of the Snake. Although minimum stream flows represent a potential mitigation measure for the effects of irrigation, they have not been implemented on a large scale in the Columbia Basin.

5.7.4 The Current Status of Agriculture/Irrigation Impacts on Fish

Agriculture currently affects anadromous fish habitat through soil erosion that causes sediment loading of streams. The toxic effects of herbicides and pesticides in runoff from farm lands is also a problem (Thompson 1976b). Farm practices, however, are tending towards minimizing erosion in order to conserve top soil. These efforts should help reduce the amount of sediment deposited in streams because of farming.

Impacts associated with irrigation continue to contribute to salmon and steelhead losses in the Columbia River Basin. A major problem in the basin is the effect of water storage, diversions and return flows on stream flow and therefore the amount of habitat available to salmon and steelhead. Flow alterations and water level fluctuations also affect the timing of life history events such as smolt out-migration. Although maintaining minimum flows for fish is becoming an important objective of fish managers, few such programs with primary considerations for fish have been implemented in the basin.

5.8 URBANIZATION/POLLUTION

5.8.1 Overview

Non-Indian settlement of the Columbia River Basin began in earnest around the mid-1800s, with many of the early immigrants settling in the Willamette Valley. In 1850, Congress passed the Donation Land Act (Act of Sept. 27, 1850, 9 Stat. 496), which gave settlers large tracts of federal land at no cost (Craig and Hacker 1940). Agriculture, mining, fishing and logging contributed to the early economy of the basin. Substantial growth occurred in the basin after completion of the transcontinental railroad around 1890. For example, from 1880 to 1890 population increased from 75,000 to 357,000 for the state of Washington; from 143,000 to 259,000 for Oregon; and from 33,000 to 89,000 for Idaho. Population also increased rapidly between 1900 and 1910 because of increased innovations in irrigation and the logging industry. Population from about 1900 to the 1980s has increased steadily (Figures 46, 47, and 48).

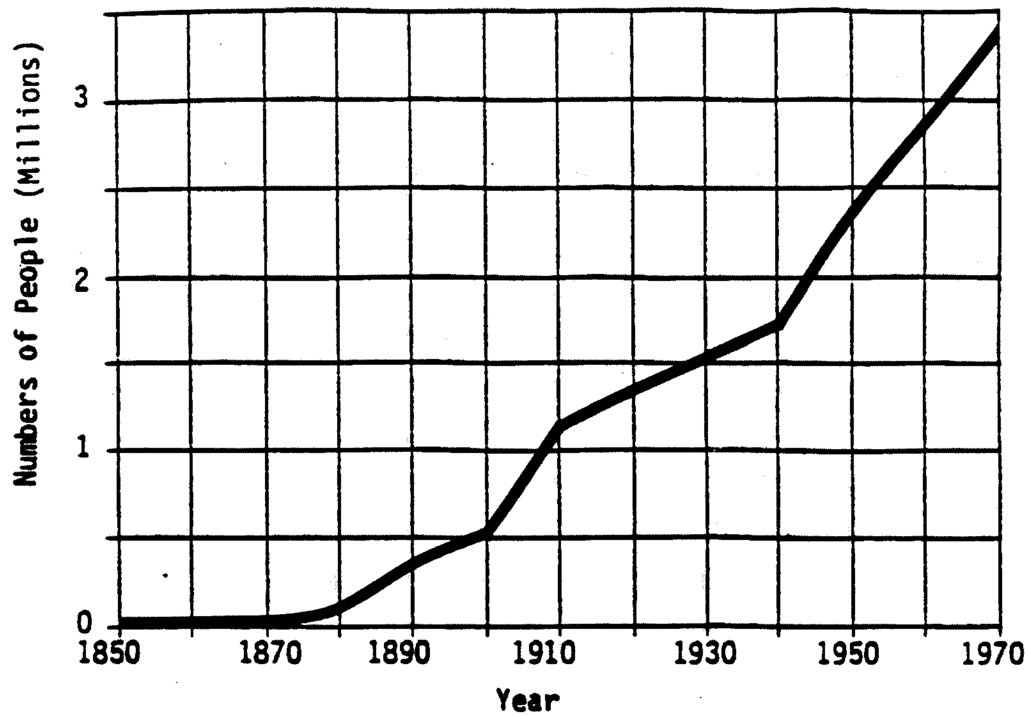

Figure 46. Population growth in Washington from 1850-1980 (U.S. Department of Commerce 1850-1980b).

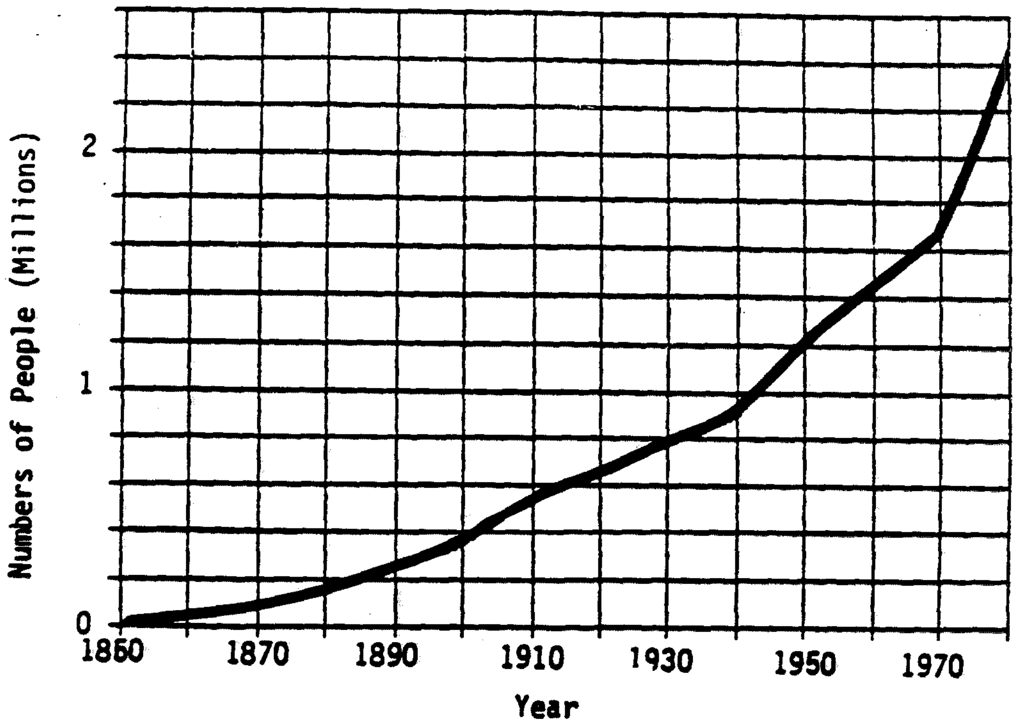

Figure 47. Population growth in Oregon from 1850-1980 (U.S. Department of Commerce 1850-1980b).

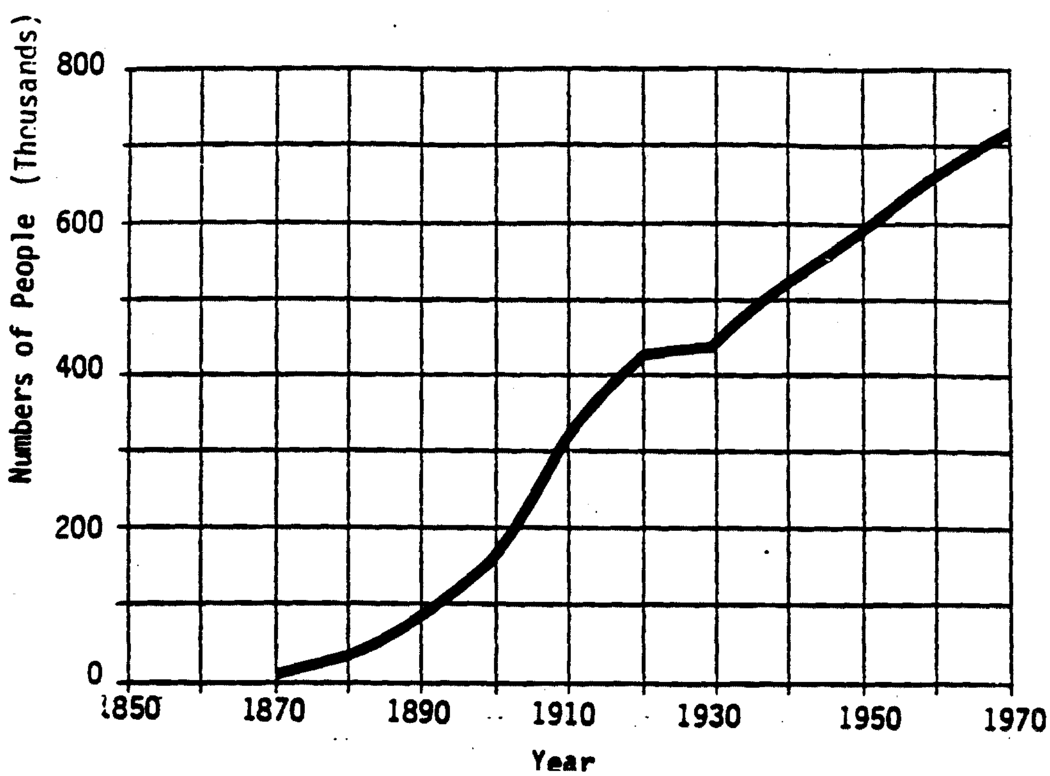

Figure 48. Population growth in Idaho 1850-1970 (U.S. Department of Commerce 1850-1970b).

Numbers of people employed in manufacturing also have been plotted (Figure 49, 50, and 51) as a means of characterizing manufacturing growth. The number of people employed in manufacturing has increased steadily except for the early 1930s (Great Depression) and 1974 to 1975 (general recession).

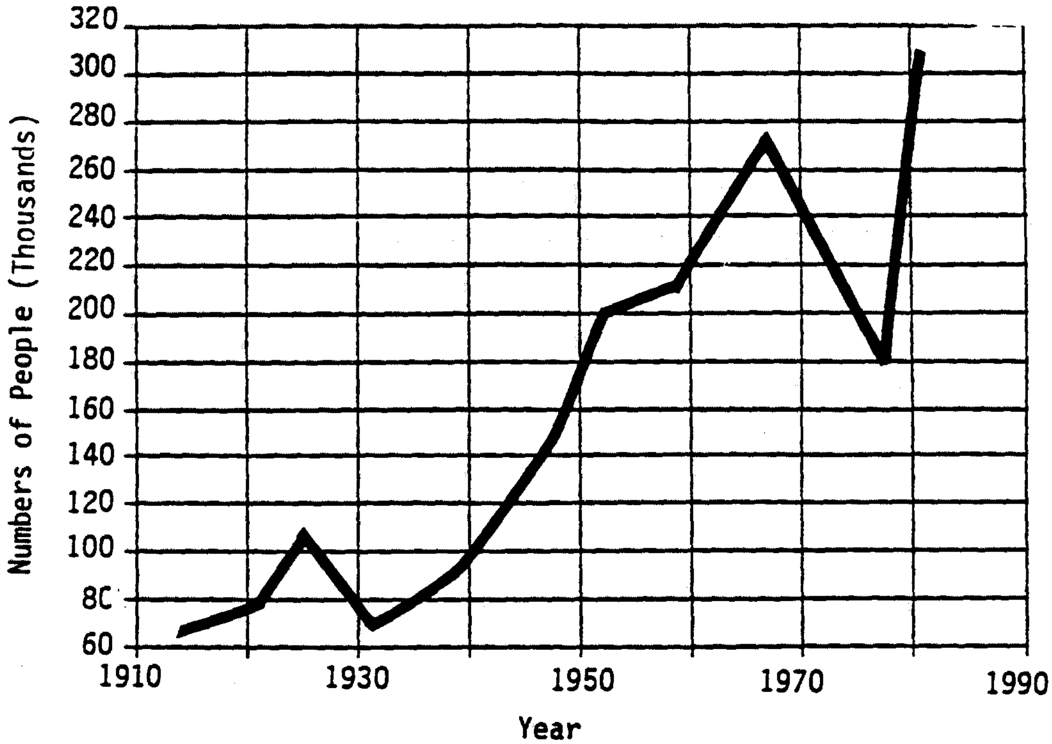

Figure 49. Numbers of people employed in manufacturing in Washington from 1910 to 1981 (U.S. Department of Commerce 1910-1981b).

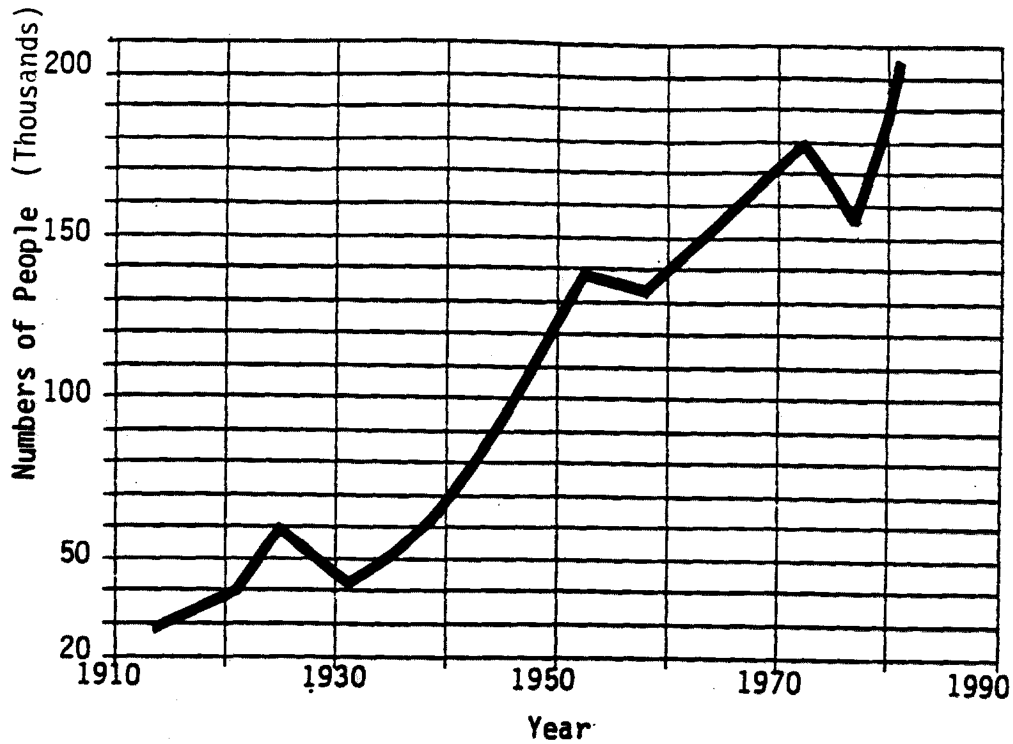

Figure 50. Number of people employed in manufacturing in Oregon from 1910 to 1981 (U.S. Department of Commerce 1910-1981b).

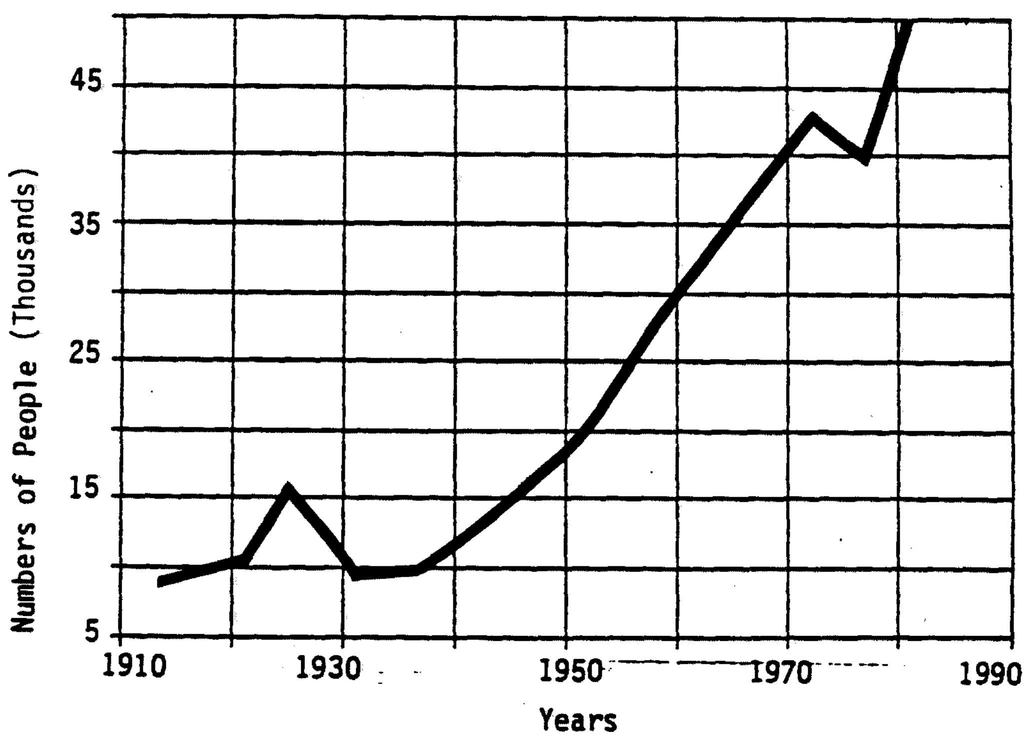

Figure 51. Number of people employed in manufacturing in Idaho from 1910 to 1981 (U.S. Department of Commerce 1910-1981b).

Urbanization of the basin brought many forms of disturbance that adversely affected the salmon and steelhead resources of the Columbia River Basin. Adverse impacts from land clearing, construction, road building, stream channelization, removal of riparian vegetation, and pollution are a few results. Of these, stream pollution in the form of discharges from various municipalities and industries probably has had the most adverse effect on the anadromous fish habitat in the Columbia Basin. Effluents from sewage treatment plants, pulp and paper mills, and aluminum plants produced most of the pollution, especially in the Willamette River Basin. Increased run-off, resulting in urban nonpoint source pollution, also has affected streams.

Concerns over water pollution were publicized in the 1940s when several studies were conducted in the Willamette River drainage and in the lower Columbia River (Fish and Rucker 1950; Fish and Wagner 1950). The Willamette River was the most heavily polluted drainage due to point source discharges (pollution from a relatively specific site as opposed to precipitation runoff). Other rivers with significant levels of local pollution included the lower Cowlitz, Umatilla, John Day, Deschutes, Klickitat, Wind, and Sandy rivers.

Major types of water pollution identified during the 1940s included reduced dissolved oxygen (DO) levels and direct toxicity due to sulfite liquours from the pulp and paper industry. Depressed DO levels were due largely to high concentrations of oxygen-consuming wastes. Metal toxicity resulted mainly from the effects of the metal mining industry.

Rapid population growth also demanded increased water supplies, which resulted in the development of dams exclusively for water supply in addition to multipurpose dams. Table 30 shows the number of dams in the Columbia River Basin used for municipal water. The two lower Columbia River areas and the two Snake River area analyses have been combined due to difficulties in separating data for these areas. The Snake River area tops the list with 24 dams used partly or exclusively for water supply. The lower Columbia River area totals 14 water supply dams; the Columbia River above Chief Joseph Dam has two; and the Columbia River area between the confluence of the Snake and Chief Joseph Dam has one.

Table 30 - Dams constructed for water supply purposes by major drainages in the Columbia River Basin.

	Built Exclusively for Water Supply Purposes	Built for More Than one Purpose, Including Water Supply
Lower Columbia River Area[1]		
Big Sandy	2	0
Columbia	5	0
Deschutes	0	1
Klickitat	1	0
Lewis	1	1
Willamette	1	1
Yamhill	2	0
	12	3
Middle Columbia River Area[2]		
Columbia	0	1
	0	1
Upper Columbia River Area[3]		
Columbia	0	1
Spokane	0	1
	0	2
Snake River Area		
Bruneau	0	1
Burnt	0	1
Clearwater	0	2
Grande Ronde	1	0
Lemhi	0	1
Little Salmon	0	1
North Fork Payette	0	1
Payette	0	3
Powder	1	0
Salmon	0	2
Snake	1	5
Wallowa	0	2
Weiser	0	2
	3	21
TOTAL FOR BASIN	15	27

[1]Columbia Basin below the confluence with the Snake River.

[2]Columbia Basin between the confluence with the Snake River and Chief Joseph Dam.

[3]Columbia Basin above Chief Joseph Dam.

The following sections describe urbanization and pollution and related impacts to salmon and steelhead resources in the six areas of the Columbia River Basin. Note that the two lower Columbia River areas and the two Snake River areas analyses have been combined due to difficulties in separating data for these areas.

5.8.1.1 Lower Columbia River Area

Population growth, urbanization, and the resulting water pollution are most extreme in the Willamette River Basin, especially in the middle and lower portions. During the 1940s, the accumulation of various wasteloads dumped into streams in the Willamette drainage created an "oxygen block" to migrating fall salmonids (Fish and Rucker 1950). Dissolved oxygen levels frequently decreased to below 3.0 parts per million throughout the summer in the lower Willamette River, particularly in the Portland harbor area. The low concentrations usually disappeared in mid- to late September with increased river discharge (Fish and Wagner 1950). According to Fish and Wagner (1950), Willamette River tributaries that suffered serious or potentially serious pollution problems were the Long Tom, Marys, Rickerall, South Santiam, Yamhill, Molalla, Pudding, Tualatin, and Clackamas rivers.

Drainages cited as potentially hazardous to fish life in 1943 because of pollution include Camas, Multnomah, and Columbia Sloughs and the lower Cowlitz River (Fulton 1970). The pulp and paper industry, as well as domestic sources, were responsible for this pollution.

In 1971, 19 thermal, 15 industrial, and 21 domestic point sources contributed to the pollution load in the lower Columbia River below Bonneville Dam (Fulton 1970). Besides localized increases in water temperature due to thermal effluents, pollutants included organic and inorganic solids (mostly wood products), suspended combustible solids (from pulp and paper mills), mercury compounds, phenols, cyanides, fluorides, chlorine, thiosulfates, organic phosphates, and acrolein.

Recent studies at the John Day fishway indicate that concentrations of heavy metals (cadmium, copper, lead, and zinc) and fluoride may be at concentrations high enough to modify behavior of migrating salmonids (Damkaer and Dey 1985). The source of these pollutants is discharge from a nearby Martin-Marietta aluminum plant. Although research results are inconclusive, it appears that fluoride concentrations near 0.5 milligrams per liter may delay migration of fall chinook salmon, by causing them to avoid the area (Damkaer and Dey 1985). Discharges of fluoride were greatly reduced in 1983 and thereafter when the aluminum plant began using a landfill storage system for pollutants (Damkaer and Dey 1985).

5.8.1.2 Columbia River Between Its Confluence with the Snake River and Chief Joseph Dam

The major cities in this region are Richland, Kennewick, Pasco, and Wenatchee, Washington. The major point source effluent of pollution identified for this area is the cooling water discharges from the dual-purpose Nuclear Reactor/Hanford Generating Project (HGP) and from Washington Public Power Supply System Nuclear Project No. 2 (WNP-2). These discharges are controlled by National Discharge Elimination System and other permits. There have been no ecologically significant thermal discharges in the Hanford Reach since January 1971 when the last single-purpose plutonium production reactor was closed down. Currently, no water quality problems due to non-point or point sources have been identified as adversely affecting the anadromous fish resources in this area.

5.8.1.3 Columbia River Above Chief Joseph Dam

Urbanization in this area has been largely confined to development along the Spokane and Coeur d'Alene River drainages. Pollution resulting from the urban surroundings of Spokane, Washington, and Coeur d'Alene, Idaho, have largely been masked by substantial pollution from the metal industry (both mines and smelting operations). As discussed previously (Section 3.1.1), these streams are outside the currently accessible natural habitat for salmon and steelhead.

5.8.1.4 Snake River Area

Urbanization and population growth in Idaho (Snake River Basin) have not been as great as in Washington and Oregon, as indicated by the population numbers and numbers of people employed in manufacturing (Figures 46 and 50). The main urban center in this area is Boise, Idaho. The probable effects of urbanization on anadromous fish include localized non-point source runoff of silt into streams, due to various population centers. Toxics or oxygen-consuming wastes in this subbasin do not appear to be a major problem with respect to the anadromous production.

5.8.2 Reducing the Adverse Effects of Urbanization/Pollution

Measures regarding reducing the adverse effects of urbanization and water pollution are mainly related to passage of the federal Clean Water Act. The goal of the Clean Water Act was to make all the nation's navigable waterways fishable and swimmable by 1985. This legislation provided impetus and backing for passage of state water pollution control legislation in Oregon, Idaho, and Washington. The Act's controls for point sources have resulted in the rehabilitation of many miles of stream. The nagging problem of control of non-point source pollution is still a largely unresolved issue.

5.8.3 The Current Status of Urbanization/Pollution Impacts on Fish

Population in the Columbia River Basin is expected to continue to increase well into the future. Currently, there is no extensive water pollution problems in the Columbia River Basin. Certain localized problems do exist, but their long-term effect on salmonids is unknown. Although control of non-point sources of pollution is still a problem, the Clean Water Act requires local and state governments to deal with this problem. Non-point source controls over existing and new developments are required in Oregon, Washington, and Idaho's stream protection legislation.

5.9 MISCELLANEOUS IMPACTS

5.9.1 Overview

This section of the report describes the effects of nuclear power production and major catastrophic natural events.

5.9.2 Nuclear Reactor Operations (Plutonium and Power Production)

Most nuclear plant development has occurred in a 50-mile section of the river known as the Hanford Reach, located downstream of Priest Rapids Dam and above Richland, Washington. This reach is an important production area for fall chinook salmon (see section 4.4.4). Three plants were constructed between 1943 and 1945, and were followed by six additional plants constructed between 1947 and the mid-1960s (Foster 1972, U.S. ERDA 1975). All of these plants were single-purpose graphite-moderated, water-cooled plutonium production reactors. Eight of the nine plants were shut down during 1964 to 1971. The ninth plant, the dual-purpose New Production Reactor (N-Reactor) and the Hanford Generating Project (HGP), has continued to operate, and is currently scheduled to continue operation until 1993.

Presently, two nuclear power generating plants are operating in the Hanford Reach; the Hanford Generating Project and the Washington Public Power Supply System Nuclear Project No. 2 (WNP-2). Both of these plants are water-cooled. The N-Reactor, which provides steam to HGP is also water-cooled. The only other large nuclear power plant operating in the Columbia River Basin is the Portland General Electric Trojan Plant located on the mainstem of the Columbia River near Rainier, Washington. It has operated since 1975 (Yundt 1985) and is also water cooled. The WNP-2 and Trojan plants have cooling towers, and amounts of heat and radioactivity released to the Columbia River are within regulatory guidelines.

Several nuclear plant facilities and operations have been investigated regarding effects on salmon and steelhead. Effects on aquatic habitats arising from operation of electrical power generating plants involve primarily the withdrawal of water for condenser cooling and the discharge of heated water to the river. Specific areas of concern include:

- Impingement of juvenile fish on intake structures;
- Entrainment of juvenile fish in the cooling water circulation systems;
- Effects of thermal discharges on juvenile and adult fish;
- Effects of chemical discharges (chlorine, mercury, heavy metals) on juvenile and adult fish; and
- Effects of radionuclides on juvenile and adult fish.

The majority of the environmental studies conducted to determine the potential effects of nuclear power development on aquatic resources in the Columbia River Basin have occurred in the Hanford Reach (Becker 1973, Neitzel 1979). During the early years of single-purpose, Pu-production reactor operations (1943-1971), chemicals, radionucleids and elevated temperatures in the cooling water discharges were major concerns (Becker 1973b). Of the potential impacts listed above, impingement and entrainment of juvenile chinook salmon at the Hanford plants were considered the most critical problems (Neitzel 1979). Although quantitative losses were not estimated, impingement and entrainment studies indicated that chinook salmon fry produced in Hanford Reach were the predominant fish affected. To minimize these losses, the HGP eliminated gaps in the screening system and installed screen rotation and continuous washing devices in 1976. There are no significant impingement or entrainment effects at Hanford intake today (Neitzel et al. 1982). Monitoring studies conducted at the Trojan Plant from 1972 to 1982 indicated minimal losses of salmon due to impingement and entrainment. Regarding radionuclides releases in reactor effluents, the last Pu-production reactor at the Hanford site using once-through cooling was closed in 1971. Both the WNP-2 and Trojan plants have cooling towers, and the limited volumes of warm water discharge (cooling tower blowdown) are limited to levels protective of aquatic life by federal and state regulations (Bullock 1985).

Although thermal, chemical, and radionuclides discharges are considered potentially harmful to salmonids, specific instances of nuclear plant discharges that have caused reductions in Columbia River salmon and steelhead populations have not been identified (Donaldson and Bonham 1964; Neitzel 1979; Neitzel and Page 1979; Neitzel et al. 1982). Furthermore, zero or minimal discharges are required by Federal and state operating licenses, and monitoring programs are conducted to assure compliance (Neitzel 1979).

5.9.3 <u>Natural Events</u>

The eruption of Mount St. Helens on May 18, 1980, caused extensive losses of salmon and steelhead resources in the Toutle River watershed. The debris avalanche, pyroclastic flows, and mudflows destroyed an estimated 136 of the 175 miles of anadromous fish habitat in the watershed (Martin et al 1984). The natural production of salmon and trout in the Toutle River was estimated to provide an annual catch of 52,000 fish. The natural runs of salmon and steelhead in the Toutle River were augmented by the Toutle salmon hatcheries, which provided an annual smolt production of 1.4 million coho, 3.2 million fall chinook, and 240,000 winter and summer steelhead. The hatcheries, which also were destroyed by the eruption, provided an estimated annual catch of 251,500 fish.

In addition, cyclical ocean and climatic conditions, such as "El Nino," affect fish populations by altering the environment. Climatic conditions affect the amount of runoff (streamflow) in two ways. During droughts (such as in 1977) and unusually warm or cold years the snowpack can melt too early or too late, the downstream migration of juvenile salmon and steelhead during the spring can be impaired to the point where large numbers of the fish don't reach the ocean. Also, forest fires, such as the 1970 Entiat River area fire, can devastate watersheds and fish habitat.

5.9.4. <u>Other</u>

Other impacts such as flood control, recreation, and navigation, have affected salmon and steelhead resources in the Columbia River Basin. These impacts are discussed in Section 4.3 because they are generally associated with operation of multipurpose dams.

A biological impact of concern is predation on salmon and steelhead smolts by predatory species which have been introduced to the Columbia River, e.g., walleye and smallmouth bass. These impacts are currently under investigation by the Bonneville Power Administration (Gray et al, 1984).

Chapter 6
MITIGATION OF LOSSES

6.1 INTRODUCTION

In certain instances, losses of fish in the Columbia River Basin have been identified and compensated. Mitigation generally has occurred because of construction and operation of dams and is not restricted to compensating just for the impact of hydropower. It should be noted that mitigation traditionally has taken the form of artificial production. This chapter's emphasis is artificial production, but information on other forms of mitigation, such as habitat restoration and laddering, is included in some cases.

Mitigation has not always replaced the same species and stocks that were affected (in-kind). As noted above, naturally produced fish frequently have been replaced by artificially produced fish. At times, different stocks or even different species have been substituted to compensate for losses.

Nor has mitigation always occurred in the location where the losses occurred (in-place). Major segments of upriver fish production have been moved to lower river areas. In other cases, a central hatchery located on one tributary has replaced production on several tributaries.

While the precise quantification of mitigation could be useful in analyzing fish losses at specific geographic sites, it is not essential for setting a losses figure for the whole basin. A comparison of current run sizes to predevelopment run sizes reflects any increases attributable to intervening mitigation.

Analysis of the mitigation of losses is helpful in understanding, in a qualitative manner, the biological loss associated with changes in production from natural to artificial production, and also with elimination and/or movement of production on a geographic basis.

This chapter provides information concerning three major types of salmon and steelhead mitigation that have occurred in the Columbia River Basin:

first, federal multipurpose mitigation programs; second, Northwest Power Planning Council fish and wildlife program measures; and third, mitigation funded under Federal Energy Regulatory Commission (FERC) licenses for nonfederal hydropower projects. Attempts to mitigate impacts of specific activities are discussed in Chapter 4.

6.2 MITIGATION

6.2.1 Overview of Columbia Basin Mitigation

One dramatic effect of mitigation activities for hydropower and for multipurpose developments has been to strengthen fish propagation in the lower Columbia River Basin without attempting to rebuild upriver runs (see Table 31). A related effect has been to increase the proportion of hatchery fish to the overall outmigration. In 1974, for instance, 40 public agency and tribal hatcheries released 155 million juvenile salmonids in the Columbia Basin -- five times as many as were released in 1960 (Netboy 1980). By the late 1960s, hatchery production of chinook, coho and steelhead surpassed natural production (Columbia River Fisheries Council 1981). In the 1970s hatchery smolts in the mid-Columbia area were estimated to comprise up to 74 percent of spring chinook outmigrants (1.4 million wild, 4 million hatchery), 71 percent of fall chinook outmigrants (1.5 million wild, 3.6 million hatchery), and 36 percent of summer chinook outmigrants (1.2 million wild, 2 million hatchery). Another 42 percent of summer chinook outmigrants came from artificial spawning channels (National Marine Fisheries Service 1981). By the late 1970s in the Snake River, spring chinook hatchery smolts were estimated to comprise up to 75 percent of the outmigration, and steelhead hatchery smolts comprised up to 80 percent. In short, hatchery production exceeded wild production for all of these stocks in the mid-Columbia and Snake areas. Because current hatchery production is higher than when these estimates were made, the current proportion of hatchery releases to natural fish is probably higher. Thus, the shift to lower basin production has been accompanied by a dramatic and accelerating shift from naturally-spawning runs to hatchery runs.

Table 31 - Hatchery Release Program under the Columbia River Fishery Development Program.

Basinwide Releases	Releases Above Bonneville Dam		Releases Below Bonneville Dam	
	Number	Percent	Number	Percent
Fall chinook	22,425,000	33	46,500,000	67
Coho	4,500,000	22	16,350,000	78
Spring chinook	4,280,000	70	1,900,000	30
Steelhead trout	320,000	13	2,120,000	87
All Species	31,525,000	32	66,870,000	68

Releases Above Bonneville Dam	Releases Above The Dalles Dam		Releases In Bonneville Pool (Between Bonneville and The Dalles dams)	
	Number	Percent	Number	Percent
Fall chinook	1,225,000	5	21,200,000	95
Coho	0	0	4,500,000	100
Spring chinook	100,000	2	4,180,000	98
Steelhead trout	180,000	54	140,000	44
All Species	1,505,000	5	30,020,000	95

(Information provided by the Columbia River Inter-Tribal Fish Commission)

6.2.2 Federally-Funded Mitigation

6.2.2.1 The Columbia River Fisheries Development Program

In addition to mitigation programs designed to minimize or compensate for salmon and steelhead losses due to individual projects in the Columbia River Basin, mitigation for the effects of federal development has generally been provided under the Mitchell Act of 1938 (Pub. L. No. 75-502, 52 Stat. 345, 16 U.S.C. § 755). The Mitchell Act was designed to mitigate for impacts resulting from water diversions, mainstem dams, deforestation, and pollution (H.R. Rep. No. 2235, 75th Cong., 3rd Sess. 1938, and Laythe 1948; Columbia River Inter-Tribal Fish Commission 1981; National Marine Fisheries Service 1984). Congress initially appropriated $500,000 under the Mitchell Act for surveys and improvements in the Columbia River Basin to benefit salmon and other anadromous fisheries. However, because of limited funds, the major initial accomplishment under the Mitchell Act was a census and survey of most of the Columbia River tributaries (Columbia River Inter-Tribal Fish Commission 1981).

A 1946 Congressional amendment to the Mitchell Act (Public Law 79-676) was passed which removed the Congressional funding limitations for the development of anadromous fisheries in the Columbia River Basin. The amendment also authorized the federal government to use facilities and services of state conservation agencies in Idaho, Washington, and Oregon in developing the salmon resources of the basin.

The 1946 amendment provided the foundation for the establishment of the Lower Columbia River Fishery Development Program (LCRFDP) in 1949. As a result of concern over water development projects in the basin, state and federal agencies recommended that the LCRFDP be used to maintain anadromous fisheries (National Marine Fisheries Service 1981). After endorsement by the Federal River Basin Inter-Agency Committee, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation, the Corps of Engineers submitted a request for Congress to appropriate $1 million in 1949 for salmon and steelhead restoration in the Columbia River Basin.

Overall coordination of the LCRFDP from 1949 to 1970 was provided by the U.S. Department of the Interior. From 1949 to 1956, the only states involved in the program were Washington and Oregon. State involvement was controlled by the area of coverage, which included the Columbia River drainage below McNary Dam. However, in 1956, Congress instructed that the program be implemented above McNary Dam. Subsequently, Idaho became a participant in

1957 and the word "lower" was dropped from the program name (LCRFDP is hereinafter CRFDP). Another change in the program organization was that overall coordination responsibilites were transferred to the U.S. Department of Commerce in 1970. The program currently is administered by the National Marine Fisheries Service in cooperation with the U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Washington Department of Fisheries, Washington Department of Game, and Idaho Department of Fish and Game.

The CRFDP emphasized: expansion of artificial propagation; improvement of existing salmon rearing and spawning habitat in tributaries by removing log jams, splash dams, and natural rock obstructions; construction and operation of permanent fishways either to facilitate passage at partial barriers or provide access to areas not previously available to anadromous fish; and construction and operation of screens to protect downstream migrants from irrigation diversions (National Marine Fisheries Service 1981).

The majority of funds expended by CRFDP since 1949 were on fish culture (Delarm and Wold 1984). The program has helped build 22 hatcheries and three major rearing ponds. Except for the WDG and WDF Ringold rearing ponds located above the Snake River confluence, facilities and releases were concentrated in the lower Columbia River Basin (Figure 52).

Salmonid species (or races) reared at CRFDP facilities include fall and spring chinook, coho, and chum salmon, and winter and summer steelhead trout. The number of chinook, coho, and steelhead smolts released from CRFDP-funded facilities for the period 1960 to 1983 is shown in Figures 53 and 56. Chum salmon smolt releases for the period 1960 to 1978 are shown in Figure 57. Of the five species (or races) involved in the program, fall chinook salmon represented the largest number of smolts, with releases ranging from 46.6 million in 1961, to 95 million in 1977. The number of spring chinook smolt releases have been considerably lower, with numbers ranging from 800,000 in 1961, to 7.6 million in 1964 and 1981. Fall chinook salmon smolt releases reached peak numbers from 1976 to 1980; spring chinook releases peaked from 1979 to 1982. The number of coho salmon smolt releases has ranged from 6.4

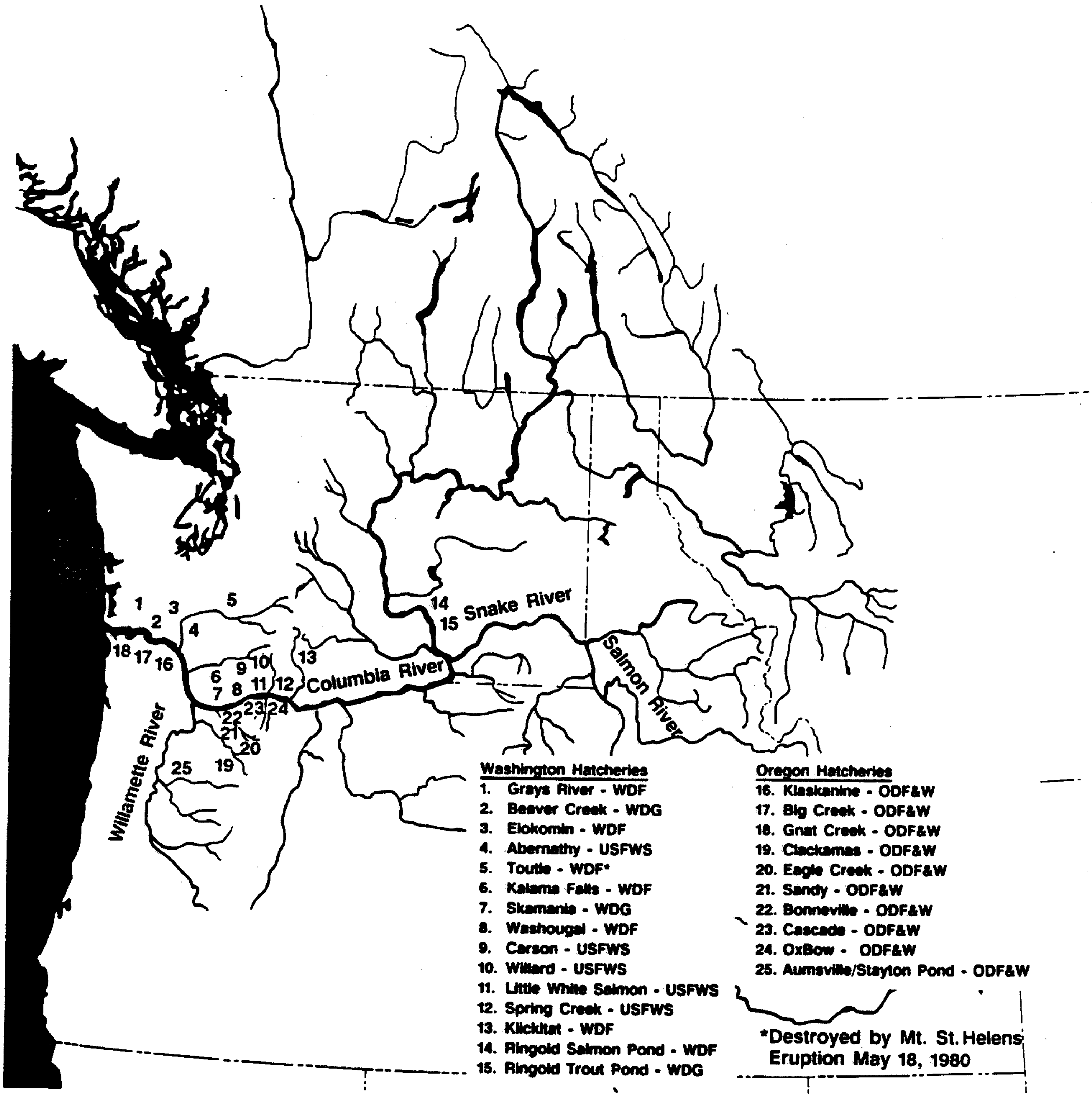

Figure 52. Hatcheries funded under the Columbia River Fisheries Development Program (Delarm and Wold 1984).

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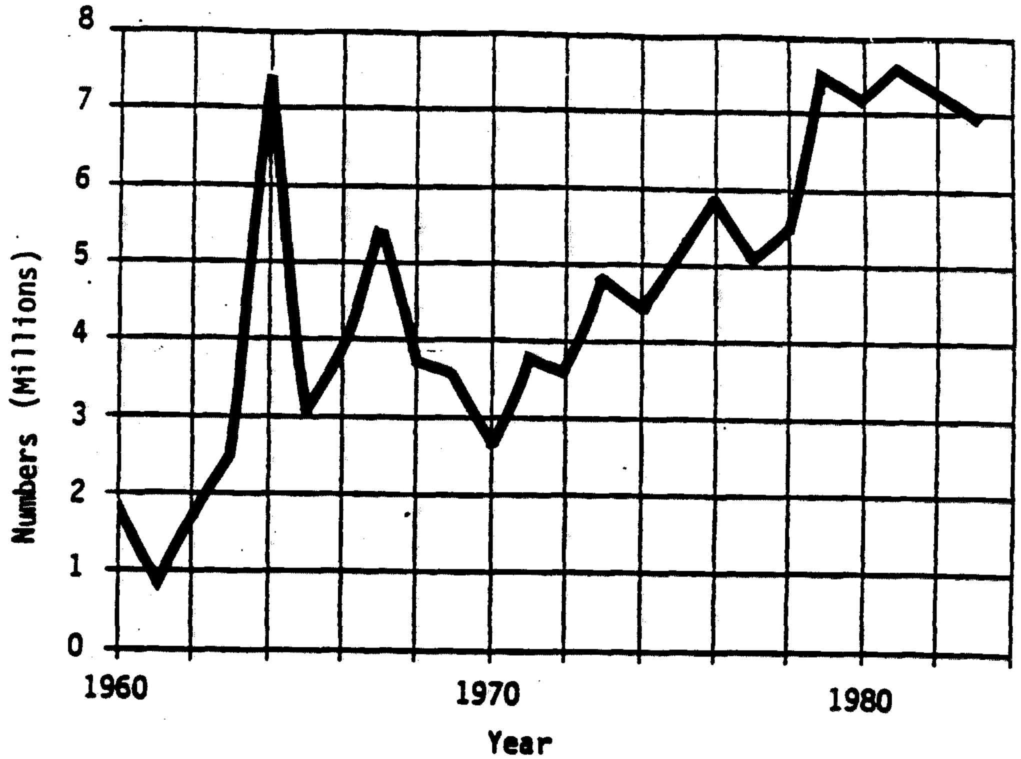

Figure 53. Columbia River Fisheries Developments Program spring chinook salmon releases (Delarm and Wold 1984).

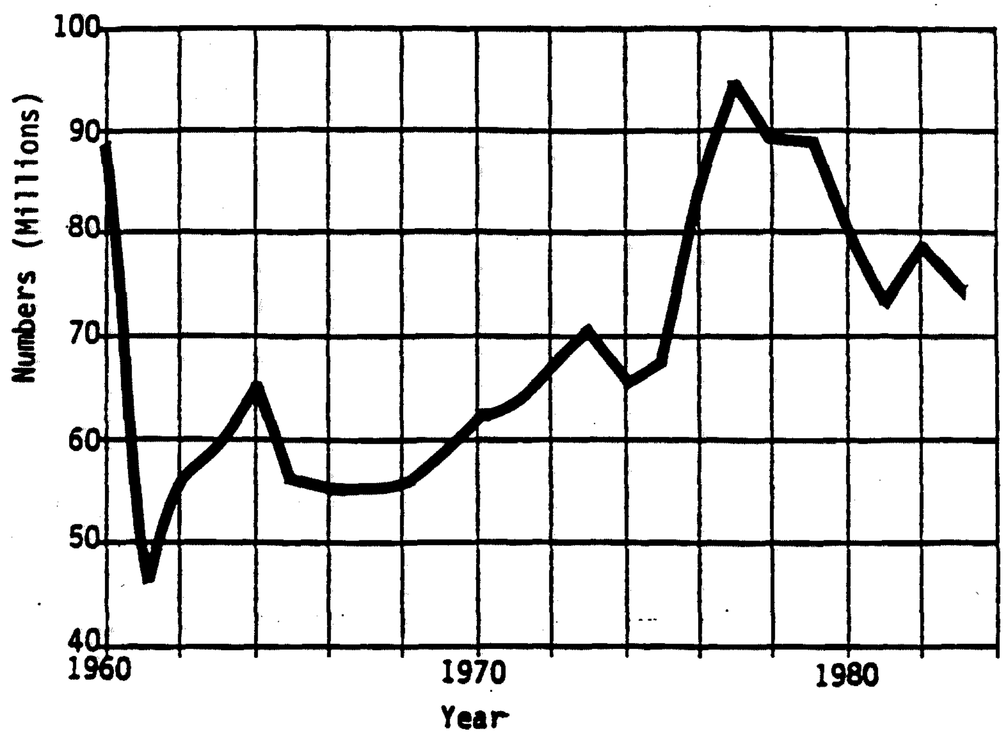

Figure 54. Columbia River Fisheries Development Program fall chinook salmon releases (Delarm and Wold 1984).

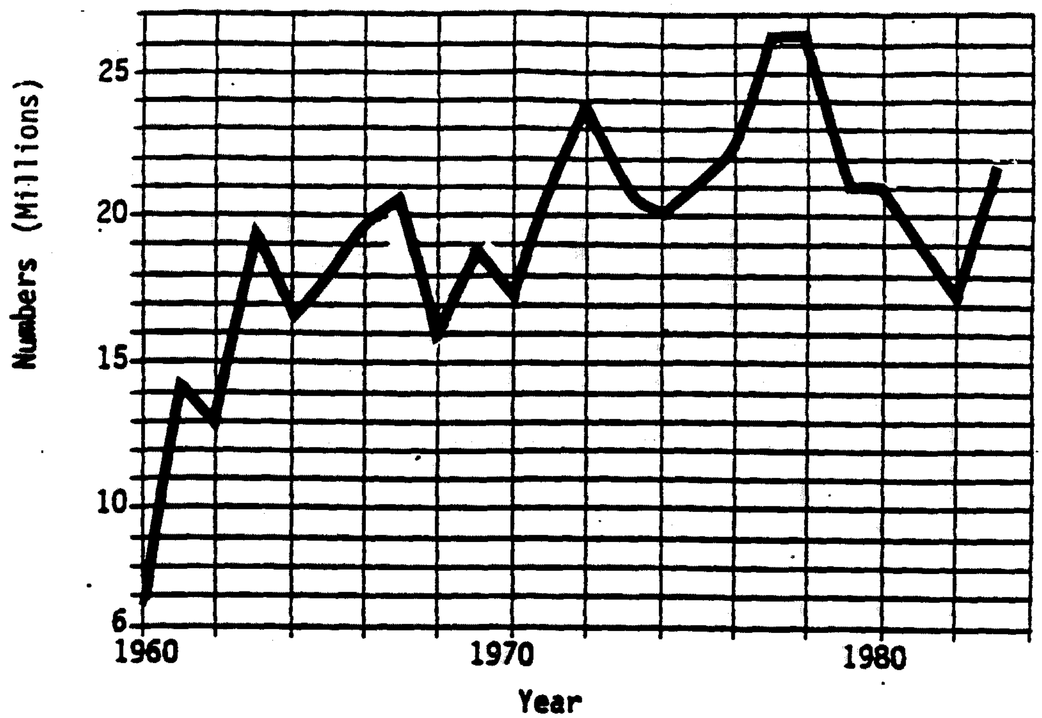

Figure 55. Columbia River Fisheries Development Program coho salmon releases (Delarm and Wold 1984).

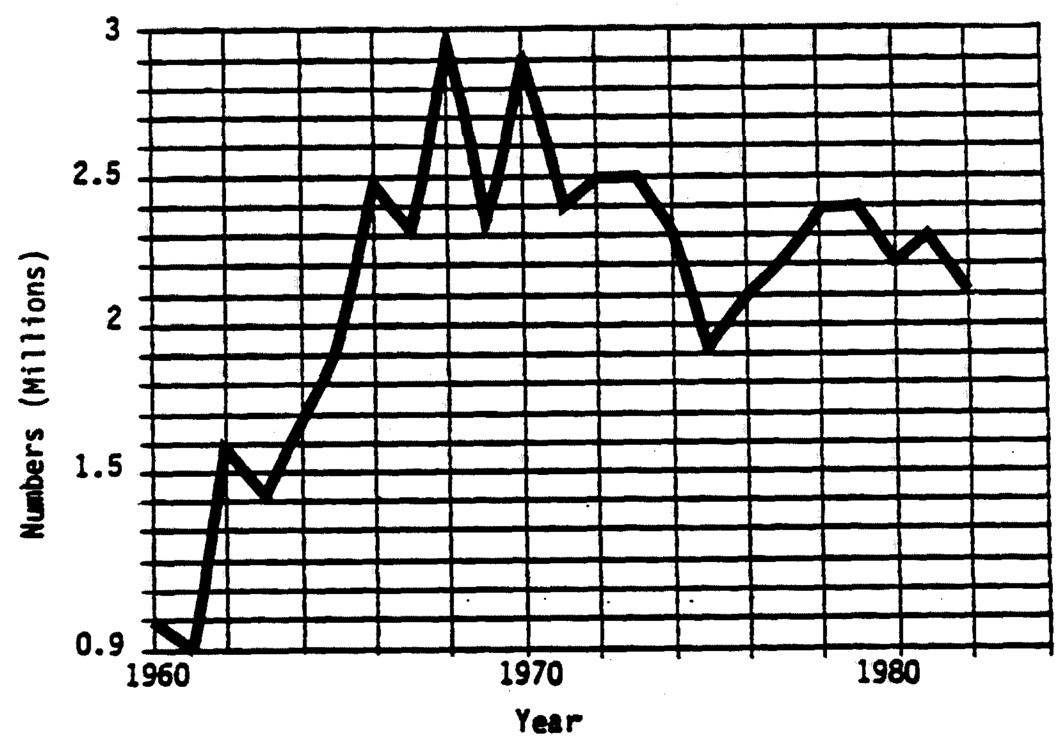

Figure 56. Columbia River Fisheries Development Program steelhead trout releases (Delarm and Wold 1984).

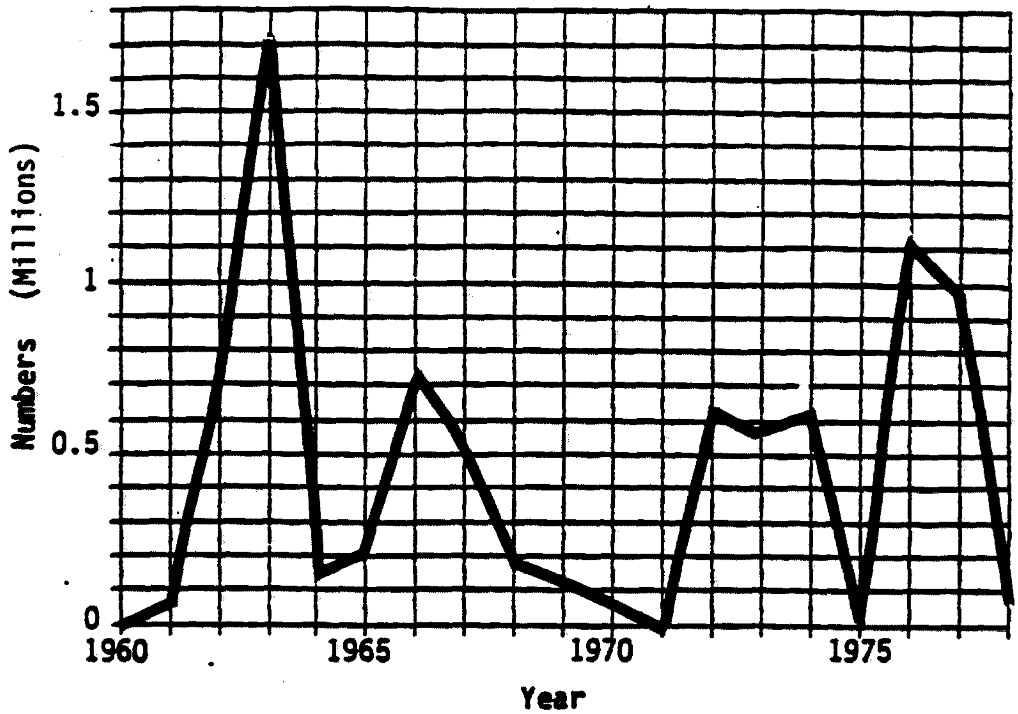

Figure 57. Columbia River Fisheries Development Program chum salmon releases (Delarm and Wold 1984).

million in 1960, to 26.3 million in 1977 and 1978. Although their numbers have fluctuated from year to year, coho releases have exceeded 20 million in most years since 1971. The number of steelhead trout smolt releases has been relatively uniform since 1961, ranging from 1.4 million in 1963, to 2.9 million in 1970. Chum salmon smolt releases have fluctuated considerably, ranging from no releases in 1960, 1971, and 1975, to 1.7 million in 1963.

The percentage contribution of smolt releases from CRDFP-funded facilities represents a large portion of all smolts released in the Columbia River Basin. During the period 1960 through 1976, the total CRFDP-funded releases comprised 74 percent of the total numbers and 57 percent of the total weight of all Columbia River Basin hatchery releases (National Marine Fisheries Service 1981).

The CRFDP also has funded the construction of fishways and removal or modification of both natural and manmade barriers affecting fish migration.

With the exception of several projects in Idaho, all construction was completed by 1970 (National Marine Fisheries Service 1981). Accumulated debris, log jams, and splash dams were removed on the Calapooia and Clatskanie rivers, as well as Big, Tide, Goble, Eagle, Deep, Clear, Abernathy, and Delph creeks (Wahle and Smith 1979).

A total of 87 fishway projects have been funded by CRFDP in the Columbia River Basin (National Marine Fisheries Services 1981). The fishways have varied in size from small, rock-cut fish passageways such as Wiley Creek in Oregon, to large, complex ladders such as those located on the Wind and Klickitat rivers in Washington and Willamette Falls in Oregon. Thirty-six fish ladders or ladder complexes were constructed under the CRFDP, which includes 18 in Washington, 16 in Oregon, and two in Idaho (National Marine Fisheries Service 1984; Armstrong 1985; Korn 1985) (Table 32). Oregon Department of Fish and Wildlife (ODFW) also operates rock-cut passes on the Yamhill, Willamina, Molalla, Santiam, and Mohawk rivers, while WDF operates several ladders on the Klickitat and Kalama rivers.

Another area of stream improvement under the CRFDP is the construction and maintenance of fish screens on irrigation diversions. Fish screen projects were initiated in Oregon in 1953, and in the early 1960s in Washington. There were 19 screens funded by CRFDP in Washington (Delarm and Wold 1984). Of these, 16 are currently operating. They are located on the Entiat, Methow, Twisp, Touchet, Tucannon rivers, and Rattlesnake Creek (National Marine Fisheries Service 1984).

Few screens were in operation in Idaho and Oregon when CRFDP projects began. There are 813 screens constructed under the CRFDP on inventory in Oregon, Washington, and Idaho. The average number of screens operating each year is 382, 12, and 196 in the three states respectively (Delarm and Wold 1984). The number of screening diversions used each year has varied, depending upon available funding and changes in irrigation withdrawal methods. Oregon and Idaho operated and maintained approximately 380 and 200 screens, respectively, during 1984 (Delarm and Wold 1984). The Oregon screens are located mainly on the John Day and Wallowa rivers; Idaho

Table 32 - Fish ladders or ladder complexes operated under the Columbia River fishery development program.[1]

Agency	Ladder	Location
Oregon Department of Fish and Wildlife	Barth Falls	North Fork Klaskanine River
	Bonnie Falls	North Fork Scappoose Creek
	City of Lostine Dam	Lostine River
	Clatskanie Falls	Clatskanie River
	Eagle Creek Falls	Eagle Creek
	Elkhorn Falls	Little North Santiam River
	Fifteenmile Creek Falls	Fifteenmile Creek
	Goble Creek Falls	Goble Creek
	Minam River Falls	Minam River
	Oregon Iron and Steel Dam	Tualatin River
	Pegleg Falls	Callawash River
	Punchbowl Falls	West Fork Hood River
	Sheepridge Dam	Lostine River
	Sherars Falls	Deschutes River
	Threemile Dam	Umatilla River
	Wiley Creek Falls	Sanitam River
	Willamette Falls	Willamette River
Washington Department of Fisheries	Cameron	Abernathy Creek
	Casteel	Klickitat River
	Cedar Creek	Lewis River
	Delimeter	Cowlitz River
	Johnson	Lewis River
	Klama Falls	Kalama River
	Klickitat #2	Klickitat River
	Klickitat #5	Klickitat River
	Little Kalama (3 ladders)	Kalama River
	Ostrander (2 ladders)	Cowlitz
	Shippard Falls	Wind River
	Trout	Wind River
	Washougal	Washougal River
	Winkler	Washougal River
	Pioneer	Wenatchee River
	Methow Valley	Methow River
	Fulton and Chewack	Chewack River
Idaho Department of Fish and Game	Middle Fork	Middle Fork Salmon River
	Selway	Selway River

[1]Sources: National Marine Fisheries Service (1981); Armstrong (1985); Korn (1985).

screens are in the Salmon River drainage. It is estimated that the screening program in Idaho has reduced mortalities by over one million juvenile chinook salmon and steelhead trout annually (Mallet 1970).

6.2.2.2 Lower Snake River Compensation Plan

In 1976, Congress authorized funding of a Corps of Engineers program to mitigate for fish losses caused by construction and operation of the four lower Snake River hydroelectric projects: Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams. This program has involved the construction of major hatcheries, the expansion and modernization of existing hatcheries, and the construction of acclimation ponds.

Above Lower Granite Dam, the program has modernized and expanded the McCall (summer chinook), Hagerman (steelhead), Crystal Springs (steelhead), and Dworshak hatcheries (spring chinook and steelhead), and constructed the Sawtooth Hatchery (Table 33). In addition, a major new facility is being constructed on the Clearwater River (Clearwater Anadromous or Dworshak II Hatchery) to rear spring chinook and steelhead.

Between Lower Monumental and Little Goose dams, the program funding was used to build the Lyons Ferry Hatchery. This facility primarily produces steelhead, but considerable fall chinook production is scheduled for the future. Steelhead from Lyons Ferry are outplanted in several tributaries in the lower Snake drainage and in the Walla Walla River. The Tucannon Hatchery also has been acquired under this program. In addition, the program included funding for the construction of Lookingglass Hatchery in Oregon for spring chinook production, and Irrigon/Wallowa Hatchery, for steelhead production.

Mitigation required to compensate for losses from construction and operation of the lower Snake River dams was computed by Salo (1974) (Table 34, columns 1 through 5). Salo estimates annual losses as 134,500 salmon and steelhead. Losses for these dams has also been calculated by Junge (1980) (Table 34, column 6). Junge estimates annual losses as 262,400 salmon and steelhead for the Lower Snake River dams.

Table 33 - Hatchery Release Program under the Lower Snake River Compensation Plan.

	Species	Number
Idaho		
McCall	Summer chinook	1,000,000
Hagerman	Steelhead	
Magic Valley (Crystal Springs)	Steelhead	4,400,000
Sawtooth	Spring chinook	2,350,000
Clearwater	Spring chinook/	1,700,000
	Steelhead	2,500,000
Dworshak	Spring chinook	750,000
Washington		
Lyons Ferry	Spring chinook/	132,000
	Fall chinook	9,162,000
	Steelhead	1,640,000
Tucannon	Steelhead	
	Spring chinook	
Oregon		
Lookingglass	Spring chinook	1,390,000
Irrigon/Wallowa	Steelhead	1,677,600
TOTAL ALL SPECIES		26,701,600

Table 34 - Estimated annual losses of salmon and steelhead due to the Lower Snake River Dams.

Species	McNary Dam Average Counts (1957-63)	Percent of Run Entering the Snake River	Snake River Run	Operational Loss Due to Lower Snake River Dams	Loss Due to Lower Snake River Dams (Salo 1977)	Loss Due to Lower Snake River Dams (Junge 1980)
Fall chinook	97,500	33	32,700	48	20,700	33,800
Spring/summer chinook	222,100	55	122,000	48	58,700	123,600
Steelhead	172,600	67	114,000	48	55,100	105,000
				TOTAL	134,500	262,400

6.2.2.3 Grand Coulee Dam

The U.S. Bureau of Reclamation constructed Grand Coulee Dam in 1941 thereby blocking the migration of salmon and steelhead above this point in the river (see Chapters 4 and 5). Mitigation for this project relied on included collection of fish from the Rock Island Dam fish ladders from 1939 to 1943. Fish were used to establish natural spawning runs in the Wenatchee, Entiat, and Okanogan rivers, as well as to supply brood stock to the Leavenworth Hatchery. Three hatcheries (Leavenworth, Entiat, and Winthrop) are currently part of this program. Present production includes 3 million spring chinook and 0.15 million steelhead at Leavenworth, 1.5 million spring chinook at Entiat, and 0.89 to 1.0 million spring chinook at Winthrop.

6.2.2.4 Corps of Engineers' Willamette River Project

The Corps of Engineers operates four hydroelectric complexes in the Willamette Basin for which salmon and steelhead mitigation, in the form of artificial production, is provided. These are Cougar, Detroit-Big Cliff, Green Peter-Foster, and Lookout Point-Dexter dams (Corps of Engineers 1981).

Mitigation for the Cougar Dam is provided by McKenzie Hatchery. This hatchery was constructed to produce 80,800 pounds or 606,000 spring chinook salmon and steelhead smolts annually to replace estimated losses of 4,060 spring chinook salmon formerly using the South Fork above Cougar Dam (Corps of Engineers 1981).

Detroit-Big Cliff Complex mitigation replaces losses of fish formerly migrating above these projects. The Minto Barrier Dam downstream from Big Cliff Dam on the North Fork Santiam deflects adult fish into holding ponds from which they are transported to Marion Forks Hatchery. Propagation facilities at Marion Forks produce 86,141 pounds or 795,000 spring chinook salmon and steelhead smolts annually (Corps of Engineers 1981).

Mitigation for the Green Peter-Foster complex is provided by the South Santiam Hatchery below Foster Dam. This hatchery produces 56,121 pounds or 322,000 spring chinook salmon and steelhead smolts annually to replace project-inundated spawning grounds (Corps of Engineers 1981).

Adult fish collection and holding facilities are provided at the base of Dexter Dam to provide for compensation of the Lookout Point-Dexter Complex. Facilities also are sited at this location for egg taking and fertilizing. Fertilized eggs are taken to Oakridge Hatchery for hatching and rearing. Propagation facilities at Oakridge Hatchery produce 181,800 pounds or 2.39 million smolts annually to replace those spring chinook salmon and steelhead formerly migrating above these projects (Corps of Engineers 1981).

6.2.2.5 Lower Columbia River Corps of Engineers Dams

There are four Corps of Engineers dams on the Lower Columbia River; Bonneville, The Dalles, John Day, and McNary dams. The mitigation required to compensate for losses caused by these dams has been computed by Junge (1980) (Table 35). Losses are computed as 539,000 salmon and steelhead annually.

Table 35 - Annual losses of salmon and steelhead due to Lower Columbia River dams (Junge 1980).

Species	Loss from Lower Columbia River Dams
Spring chinook	108,000
Summer chinook	73,000
Fall chinook	143,000
Sockeye	72,000
Steelhead	143,000
	539,000

6.2.3 Pacific Northwest Electric Power Planning and Conservation Act of 1980

The other major program underway to restore salmon and steelhead resources in the Columbia River Basin is under the auspices of the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act). The Northwest Power Act required the Northwest Power Planning Council to develop a Columbia River Basin Fish and Wildlife Program consisting of measures to protect, mitigate and enhance fish and wildlife affected by the development, operation and management of hydroelectric facilities in the Columbia River Basin. The Council's fish and wildlife program includes measures to improve downstream passage; upstream passage; and wild, natural, and hatchery propagation. Various federal agencies are currently implementing the program.

6.2.4 Non-Federally Funded Mitigation

This section includes a listing of mitigation programs that are either entirely or partially non-federally funded. These program descriptions include major species reared and released at artificial production facilities. These programs may differ from year to year depending on egg availability, disease, and agreed-to program changes.

6.2.4.1 Idaho Power Company

The Federal Power Commission issued a license to the Idaho Power Company (IPCo) in 1955 for a three-dam complex in the middle Snake River consisting of Brownlee, Oxbow, and Hells Canyon dams. One provision of this license required IPCo to "construct, maintain, and operate facilities for the purpose of conserving the fishery resource of the Middle Snake River" (Idaho Power Co. 1982).

Initially these efforts consisted of measures to enhance and protect the salmon and steelhead production above Hells Canyon Dam. A program was initiated to transport adult and juvenile salmonids around the three projects. However, an evaluation of the transportation program, begun in 1961, indicated that while spawning of transported adults was apparently successful, total numbers of downstream migrating juveniles were declining. Juvenile fish were apparently not successfully migrating through the reservoirs, and were displaying a high rate of residualism (Ebel, personal communication).

Today, the Oxbow, Rapid River, Niagara Springs and Pahsimeroi hatchery complexes constitute the IPCo mitigation program. Oxbow is used primarily as an adult holding facility, although provision exists to update the facility for fall chinook production. Rapid River Hatchery is designed to produce about three million spring/summer chinook smolts; two million are released on-station, while the remaining third are released into Hells Canyon. Adults are collected at the hatchery and at an adult trapping facility in Hells Canyon.

Steelhead production at the Niagara Springs and Pahsimeroi facilities follows two paths. The first involves adults collected at the Hells Canyon adult trap, held and spawned at Oxbow Hatchery, reared at Niagara Springs and released back into Hells Canyon. In the second path, adults are collected at the Pahsimeroi facility, the juveniles are reared at Niagara Springs, and then released into the Pahsimeroi. These two programs are intended to produce about 3.2 million steelhead smolts annually.

In addition to the steelhead program at Pahsimeroi, the facility is also programmed to produce about one million spring/summer chinook smolts for release into the Pahsimeroi River. Presently, this program uses Rapid River as an egg source, although the facility is intended to be self-sustaining in the future.

One commentor has reported the number of salmon and steelhead returning above Hells Canyon Dam immediately prior to 1961 when passage above this point was blocked (Table 36). Table 36 also shows the average number of fish IPCo trapped at Brownlee and Oxbow dams from 1957 to 1963 to provide brood stock for their mitigation program and the number of smolts originally required of IPCo annually to mitigate for the Hells Canyon Complex.

Table 36 - Hells Canyon mitigation.

Species	Average Returns Above Hells Canyon Dam Site Before Passage Blocked[1]	IPCo Broodstock Trapping Program at Brownlee and Oxbow Dams from 1957 to 1963 (annual average)	IPCo Mitigation Requirement for Hells Canyon Complex (pound of smolts)
Fall chinook	25,000	7,500	1,000,000
Spring/summer chinook	6,800	4,300	4,000,000
Steelhead	9,800	2,600	400,00

[1]PNRC 1976 (Report F - Compensation).

6.2.4.2 Douglas County Public Utility District

When Wells Dam was constructed in 1967, Douglas County PUD was required to construct two fishways, a spawning channel, and fish culture facilities. The hatchery and rearing pond originally produced 325,000 steelhead smolts. The channel was converted to a hatchery which presently produces 1.5 million summer chinook. As part of the 1984 Mid-Columbia PUD Settlement Agreement signed by Douglas, Chelan, and Grant County PUDs; Washington Department of Fisheries and Department of Game; Oregon Department of Fish and Wildlife; National Marine Fisheries Service; and the Yakima, Umatilla, and Colville tribes, Grant County PUD was required to supplement the Wells Hatchery with 25,000 pounds of steelhead. The Bureau of Reclamation also was allowed to use the Wells facility to produce 150,000 steelhead for release into the Okanogan drainage (Columbia River Inter-Tribal Fish Commission 1982).

In addition, the 1984 Mid-Columbia PUD Settlement Agreement requires Douglas County PUD to install and test spillbay bypass units by 1988 and to provide spill for 50 percent fish passage efficiency (up to 20 percent daily average flow over 30 days) at Wells Dam.

6.2.4.3 Chelan County Public Utility District

With the construction of Rocky Reach Dam in 1962, Chelan County PUD was required to construct a fishway to attract and collect adult migrants. Additionally, in 1968, Chelan County PUD was required to construct a spawning channel on Turtle Island to accommodate 300 pairs of fall chinook salmon. The channel was converted to a hatchery in the period 1970 to 1977. As part of the 1984 Mid-Columbia Settlement Agreement (see 6.2.4.2 for signatories), Chelan County PUD was required to continue funding for the Rocky Reach and the Turtle Rock facilities. Production goals are a total of 35,000 pounds of coho, 25,000 pounds of yearling chinook, and 30,000 pounds of steelhead at these facilities. Chelan County PUD also funds the Chelan Hatchery which produces steelhead (Columbia River Inter-Tribal Fish Commission 1982).

In addition, the 1984 Mid-Columbia PUD Settlement Agreement requires Chelan County PUD to install a mechanical bypass system by the spring of 1987 and to provide spill for 30 percent fish passage efficiency (up to 10 percent daily average flow over 30 days) at Rocky Reach Dam.

6.2.4.4 Grant County Public Utility District

Grant County PUD provides mitigation for construction and operation of Priest Rapids and Wanapum dams, constructed in 1961 and 1964 respectively. Mitigation includes a spawning channel built to accommodate 5,000 spawners completed in 1963. The channel was converted to a hatchery in 1972. The hatchery goal is 75,000 pounds of fall chinook (or equivalent numbers of other races). Up to four sections of the channel are made available to Chelan and Douglas PUDs for rearing 25,000 pounds of fall chinook. As part of the 1984 Mid-Columbia Settlement Agreement (see 6.2.4.2 for signatories), Grand County PUD was required to maintain the existing 100,000 pound capacity of yearling fall chinook at the Priest Rapids Hatchery (Columbia River Inter-Tribal Fish Commission 1982).

In addition, the 1984 Mid-Columbia PUD Settlement Agreement requires Grant County PUD to conduct spill effectiveness tests from 1985 to 1987, to install the selected bypass alternative by 1988, and to provide spill for 50 percent fish passage efficiency (13 to 27 percent daily average flow over 30 days) at Wanapum Dam. They must also install a mechanical bypass system by the spring of 1988 and annually provide spill equaling 10 to 19 percent of flow over 30 days at Priest Rapids Dam.

6.2.4.5 Portland General Electric Company

Portland General Electric Company (PGE) operates the Bull Run Project on the Sandy River, the North Fork Project on the Clackamas River, and the Pelton and Round Butte projects on the Deschutes River (Kindley 1982). A mitigation program for the Bull Run and North Fork projects provides coho and spring chinook salmon, and winter steelhead trout. This program is operated at the Clackamas Hatchery on the Clackamas River (Kindley 1982). Funding for this facility includes some Columbia River Fisheries Development Program and Oregon Department of Fish and Wildlife contributions.

The Pelton Project includes hatchery facilities with a capacity of one million spring chinook salmon eggs. The production levels of the hatchery are to maintain returns of 1,800 steelhead trout and 1,200 spring chinook salmon annually. This predicates annual production of 145,000 chinook and 180,000 steelhead trout of migrant size (Kindley 1982).

6.2.4.6 City of Tacoma

The Mayfield and Mossyrock projects on the Cowlitz River are operated by the City of Tacoma. Fish facilities at these projects include two hatcheries and a 240-acre rearing pond (Kindley 1982).

The two hatcheries (one for salmon production and the other for trout production) were constructed to compensate for losses of spring and fall chinook and coho salmon, and steelhead trout that migrated upstream of the dam sites. The salmon hatchery has a capacity of 550,000-600,000 pounds, whereas the trout hatchery's productive capacity is about 250,000 pounds (Kindley 1982).

Production levels at the salmon hatchery have been established to maintain annual adult runs of 17,300 spring chinook salmon, 8,300 fall chinook salmon, and 25,500 coho salmon. This results in annual releases of approximately 5 to 6 million fall chinook fingerlings, 3.5 to 4 million coho yearlings, and 2 to 4 million spring chinook fingerlings and/or yearlings (Kindley 1982).

At the trout hatchery, production levels are established to sustain runs of winter steelhead at about 12,000 adults. This predicates annual releases of approximately 500,000 winter run and 200,000 summer run steelhead smolts (Kindley 1982).

6.2.4.7 Eugene Water and Electric Board

Eugene Water and Electric Board (EWEB) owns and operates the Carmen Smith, Leaburg, and Walterville Projects. The Carmen Smith complex compensates for losses with an artificial spawning channel for steelhead. Mitigation for the other EWEB projects is accomplished with operational shutdown during outmigrant timing and flow releases for migrants (Kindley 1982).

6.2.4.8 Pacific Power and Light Company

Pacific Power and Light operates the Merwin, Yale, and Swift projects on the Lewis River. Fishery facilities include two hatcheries that produce coho and fall chinook salmon, and steelhead trout (Kindley 1982).

They also operate Condit Dam on the White Salmon River. Passage was originally provided at this project with a wooden ladder that was washed out and rebuilt and subsequently washed out. No artificial production mitigation was provided for the project.

6.2.4.9 City of Portland

The Bull Run Dam in the Sandy Basin provides for Portland's municipal water supply. In order to mitigate for fish losses caused by this dam, Portland has agreed to fund expansion of the Clackamas Hatchery that will provide annual production of 30,000 pounds of spring chinook salmon and 20,000 pounds of summer steelhead. Placement (release location) of this production is up to the discretion of the Oregon Department of Fish and Wildlife.

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