

History of Artificial Propagation of Coho Salmon, *Oncorhynchus kisutch*, in the Mid-Columbia River System

ROY J. WAHLE and ROGER E. PEARSON

Introduction

Since the beginning of the 20th century, fish managers in the mid- and upper Columbia River have turned to hatcheries for a supply of anadromous fish. Prior to its settlement, the area was noted for its natural Pacific salmon *Oncorhynchus* spp., resources; but, as these resources began to decline, artificial propagation was attempted.

The first hatcheries in the mid-Columbia section (Fig. 1) of the river—the area formed by the tributaries and main stem of the Columbia above the mouth of the Snake River, at river mile 325, to Chief Joseph Dam at river mile 545—were

constructed on the Wenatchee and Methow Rivers in 1899. By 1914 both had ceased operation. A new hatchery was constructed on the Wenatchee River in 1913 and one on the Methow River in 1915, both downstream from

Roy J. Wahle, now retired, was with the Northwest Regional Office, National Marine Fisheries Service, NOAA, 847 N.E. 19th Avenue, Suite #350, Portland, OR 97232. Current address: Rt. 2, P.O. Box 21, Yamhill, OR 97148. Roger E. Pearson is with the NMFS Northwest and Alaska Fisheries Center, 2725 Montlake Boulevard East, Seattle, WA 98112.

ABSTRACT—The history of artificial propagation of coho salmon, *Oncorhynchus kisutch*, in the mid-Columbia River region began in 1899 with the construction of salmon hatcheries on the Wenatchee and Methow Rivers by the Washington Department of Fish and Game. These early attempts at artificial propagation ended in 1931. In the early 1940's, the Federal Government, in a program to resume propagation activities in the region, built hatcheries on the Wenatchee, Entiat, and Methow Rivers. These hatcheries reared several species of salmon, but ceased work on coho salmon after 30-35 years and concentrated on other species. Meanwhile, in the early 1960's, the Washington Department of Fisheries began to rear coho salmon at new facilities along the mid-Columbia River. Coho salmon were first reared at Ringold Salmon Pond near Pasco, and they were later reared at two additional facilities; one located at Wells Dam and the other upstream of Rocky Reach Dam at Turtle Rock. Since 1899, a total of over 65 million juvenile coho salmon have been artificially propagated in the mid-Columbia region and released into the Columbia River system.

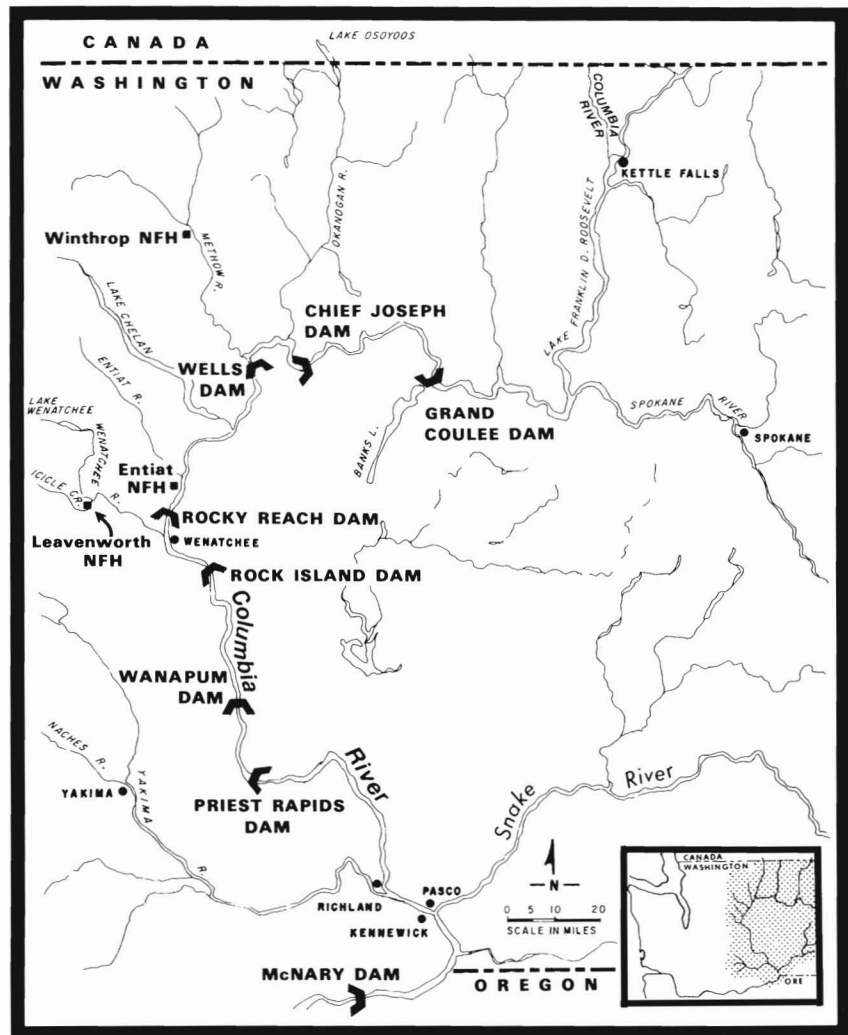
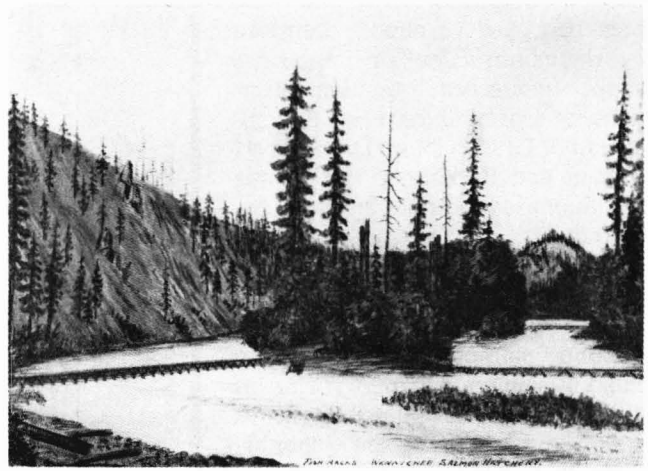


Figure 1. —Middle and upper portion of the Columbia River Basin.



Wenatchee Hatchery (left) near the Old Chiwaukum railroad station in about 1901. At right are the hatchery's fish racks which spanned the river and were erected each year following the spring-summer freshets.

the earlier locations. These early attempts at artificial propagation ceased in 1931.

Grand Coulee Dam on the upper Columbia River was built in the late 1930's, and the construction of this dam, which did not have a fishway to pass the anadromous stocks of the upper Columbia, gave rise to a major artificial propagation program (Neuberger, 1941). Large Federal hatcheries were constructed near Leavenworth, Entiat, and Winthrop, Wash., to provide runs of anadromous fish in the Columbia River Basin between Grand Coulee and Rock Island Dams (Fig. 1). Only limited success was achieved in the propagation efforts at the hatcheries. Part of the problem was that the knowledge and technology of rearing Pacific salmon and steelhead, *Salmo gairdneri*, was at an early stage of development; other handicaps centered on hatchery facilities and water supplies. In addition, the mix of species reared has varied considerably over the past 40 years, depending mainly on trends in management and advances in fish culture (Mullan¹).

¹Mullan, J. W. 1980. Ecological overview, coho salmon (*Oncorhynchus kisutch*) propagation, Mid-Columbia River. Admin. Rep. 1, 51 p. Fisheries Assistance Office, U. S. Fish and Wildlife Service, Route 1, P.O. Box 123-A, Leavenworth, WA 98826.

Following the construction of the Federal hatcheries, other artificial propagation facilities were built. All are operated by the State of Washington and most are funded by the Public Utility District (PUD) of the local area.

This article presents a brief history of the production of coho salmon, *Oncorhynchus kisutch* (also called silver or silverside), at mid-Columbia hatcheries. This article does not cover ecological information that can be used to elucidate reasons for the success or failure of hatchery operations. Instead, the article concentrates on dates of hatchery operation and numbers of fish released. Much of this information is only available in reports that have had limited distribution, and some information has never been published. This is rather surprising because at one time the hatchery operation on the mid-Columbia was North America's largest program of artificial fish propagation (Neuberger, 1941).

Of the five major river systems on the mid-Columbia (the Entiat, Methow, Okanogan, Wenatchee, and Yakima), all except the Okanogan at one time held native populations of coho salmon (Craig and Suomela², Davidson³). Considering the location of the spawning grounds utilized by this species in the regions adjacent to

the northern North Pacific Ocean, the aforementioned rivers are moderately distant from the ocean. McPhail and Lindsey (1970), on one hand, describe coho salmon spawning in the Yukon River 1,152 miles from the ocean, and Gribanov (1948) reports that on the Kamchatka Peninsula, U.S.S.R., their spawning grounds frequently extend beyond the upstream limits of sockeye, *O. nerka*; pink, *O. gorbuscha*; and chum, *O. keta*, salmon. Yet Godfrey (1965) finds it more common, at least in North America, for coho salmon to spawn within 150 miles of the ocean.

Anadromous fish runs in the mid-Columbia were influenced by agricultural practices and exploitation of resources, such as mining of metals, as early as the last half of the 19th century—as demonstrated by the need for the hatcheries constructed in 1899 on the Methow and Wenatchee

²Craig, J. A., and A. J. Suomela. 1941. Appearance of the runs of salmon and steelhead trout native to the Wenatchee, Entiat, Methow, and Okanogan Rivers. Unpubl. rep., 35 p. U.S. Fish and Wildlife Service, U.S. Department of the Interior, Seattle, Washington. (Available from Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.)

³Davidson, F. A. 1965. The development of irrigation in the Yakima River basin and its effect on the migratory fish populations in the river. Unpubl. rep., 14 p. Grant County Public Utility District, P.O. Box 878, Ephrata, WA 98823.

Rivers. Furthermore, the runs had been destroyed or almost destroyed by the construction of impassable dams, unscreened irrigation diversions, and overharvest prior to completion of Grand Coulee Dam in 1941 (Bryant and Parkhurst, 1950; Craig and Suomela, footnote 2; Davidson, footnote 3).

Abundance and Life History of Columbia River Coho Salmon

Coho salmon are second to chinook salmon, *O. tshawytscha*, as the most numerous salmon species in the Columbia River Basin. Columbia River coho salmon support extensive commercial and sport fisheries off the Pacific Coast from northern California to southern British Columbia as well as a major river fishery (Lander and Henry, 1973; Wahle et al., 1974).

Over the years, the catch of coho salmon in the Columbia River has varied extensively (Craig and Hacker, 1940; Fulton, 1970). It is evident, however, that coho salmon were most abundant in the early years of the fishery when annual catches reached 700,000-900,000 fish, and that they declined rapidly in the late 1930's (Fig. 2). Catches remained low until the mid-1960's when hatchery production increased sharply.

Data do not exist on the early abundance of mid-Columbia coho salmon. The records of early settlers, however, indicate that virtually all of the streams in this area supported relatively large runs of coho salmon (Bryant and Parkhurst, 1950; Craig and Suomela, footnote 2; Davidson, footnote 3).

At one time, the Columbia River was the greatest salmon and steelhead river in the world. The fish originated in the thousands of miles of streams, migrated to the ocean, grew to adulthood, and migrated back to their natal streams to spawn and die, completing the life cycle. The population did not consist of one large mass of fish that randomly distributed itself throughout the system, with free interbreeding occurring between all fish. Instead, a complex of subpopulations evolved with segregated

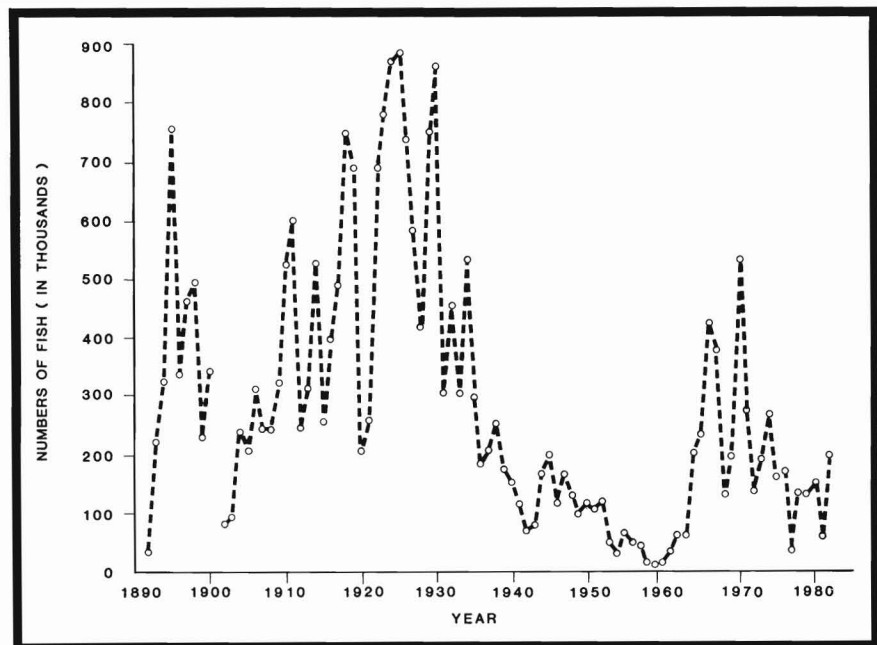


Figure 2.—Commercial catch of coho salmon (by net) in the Columbia River, 1891-1982.

Table 1.—Available information on spawning of coho salmon at Leavenworth and Winthrop National Fish Hatcheries (from Mullan, text footnote 1).

Hatchery and year	Arrival dates	Spawning dates	No. fish spawned		Average no. of eggs/female
			Males	Females	
Leavenworth					
1940			4	2	3,700
1941		10/24-11/7	4	6	2,600
1944	9/30-11/7	10/10-11/8	57	66	3,077
1945			3	1	2,947
1947		10/28-11/28	72	80	2,635
1950		12/7			2,421
1966			49	51	3,078
1967			7	11	2,727
1968	9/13	10/2	375	689	3,027
1970	10/20	11/18	236	204	3,317
1971				408	3,126
1972				7	3,143
1973	8/30-10/29	10/29 ¹	28	39	3,017
Winthrop					
1947 ²		11/13-12/3			2,092
1950		10/25-12/10	9	7	3,806
1953			3	3	2,824
1954			2	1	2,954
1962 ³	10/9	10/10	64	119	2,926

¹Peak of spawning.

²Fish reported in poor condition; some were spawned out.

³Fish reported in excellent condition.

spawning units (Mullan, footnote 1).

Mullan (footnote 1) has reported that records of arrival and spawning dates for coho salmon returning to the Leavenworth and Winthrop National Fish Hatcheries (NFH) of the mid-Columbia are incomplete and inconsistent (Table 1); and there are no

records of adults returning to Entiat NFH. Indigenous (i.e., mid- and upper Columbia River) coho salmon held at Leavenworth NFH on the Wenatchee River were known to have spawned in late October-early November in 1941 and 1944. Nonindigenous stock returning to Winthrop

NFH on the Methow River were spawned into December in some years; the fish were reported to be in poor condition and partially spawned out. Likewise, fish counting in the 1970's was extended into late November or mid-December at Rock Island and Rocky Reach Dams to count large numbers of coho salmon passing during this period.

Adult coho salmon enter their streams of origin between July and February and spawn from September through March. The species is categorized into seasonal runs depending on the time of year that adult fish arrive in the river to spawn. Late summer and fall runs are the stocks that are usually used in hatcheries.

Coho salmon spawn in the fall or winter, and the resultant fry emerge from the gravel in early spring. Nearly all Columbia River fry remain in fresh water for 1 year prior to migration to the ocean in the spring of their second year of life. Some male coho salmon spend only about 6 months in the ocean before returning to their natal stream to spawn. These fish, said to be 2 years old, are called jacks. Most Columbia River fish, however, spend about 18 months in the ocean and return to spawn as 3-year-olds (Marr, 1943).

Egg number varies with body size, geographical area, and year. In Washington, this number ranges from 1,440 to 5,700 for females 17.3-28.3 inches in length. The numbers range from 2,100 to 2,789 in British Columbia where the usual weight of commercially caught fish is 8 pounds, with most ranging from 5 to 12 pounds and with 20-pound fish not uncommon (Scott and Crossman, 1973).

Mullan (footnote 1) reported that the data on average number of eggs per female spawned at Leavenworth and Winthrop NFH are relatively complete, but that data on size of fish spawned are almost totally lacking (Table 1). Fulton (1970) reported that coho salmon returning to Leavenworth NFH in 1968 weighed 12-15 pounds compared with an average weight of 9.9 pounds for Columbia River fish. Although none returned to

Leavenworth NFH, progeny of Lewis River coho salmon that were reared at Leavenworth NFH and then recovered as adults during 1945 in the lower Columbia River commercial fisheries were smaller than the above; 89 females averaged 9.6 pounds and 27.0 inches, and 121 males averaged 9.3 pounds and 26.3 inches (Fulton and Pearson, 1981). The average number of eggs per female was about 3,000 at Leavenworth and Winthrop NFH (Table 1).

Artificial Propagation Before Construction of Grand Coulee Dam

Although there are five major river systems in the mid-Columbia, artificial propagation was only carried out in two, the Wenatchee and Methow, prior to construction of Grand Coulee Dam. Both rivers flow southeasterly from the Cascade Mountains and are primarily maintained by melting snow and glaciers. There is about a 50-inch difference in precipitation between the subalpine forests of the headwaters and the semiarid region at the confluences with the Columbia River in north-central Washington. These are gravelly rivers, with wide fluctuation in flow associated with the climatic and geological characteristics of the region (Mullan, footnote 1).

Wenatchee River

The first hatchery on the Wenatchee River was constructed in 1899 about 40 miles upstream from the Columbia River near the (then) Chiwaukum railroad station above Tumwater Canyon (WDFG, 1902). In 1904 the hatchery was closed. Reasons given for the closure were extreme cold weather, heavy snow, isolated location and consequent expense of operation, freshets, and that it was too far up the river to secure the best variety of fish which was spring chinook salmon. A quotation from the 14th and 15th annual reports of the State Fish Commissioners of Washington states: "If it [the hatchery] had been below the Tumwater Canyon, the early chinook could have been secured; as it is it

takes only an inferior run of silver-sides" (WDFG, 1903-04).

The next hatchery on the river began to propagate fish in 1913. This state facility was constructed farther downstream, about 25 miles upstream from the Columbia at the town of Leavenworth. An important reason for selecting this location was the premise that large numbers of spring chinook salmon could be taken. However, few eggs of spring chinook salmon or any other species were obtained at this site, and the hatchery was abandoned in 1931. Data, which are probably incomplete, indicate that two lots of coho salmon eggs were collected, 30,000 and 38,500, and one lot of 3.8 million fry planted (1903) that were progeny of lower Columbia River stocks (Craig and Suomela, footnote 2).

Methow River

The first hatchery on the Methow River was built in 1899 at the mouth of the Twisp River. It produced mainly coho salmon. Almost 12 million coho salmon eggs were taken from 1904 to 1914 (Craig and Suomela, footnote 2).

In 1915, at Pateros near the mouth of the Methow River, the Washington Water Power Company constructed a dam which was not provided with fishways (Bryant and Parkhurst, 1950). Since the dam was impassable, the hatchery was moved downstream of the dam site. Coho salmon eggs continued to be taken—about 3.5 million from 1915 to 1920. The run declined following the move, and no eggs were taken after 1920, although the hatchery continued to operate until 1931 with eggs and fry of steelhead and chinook and chum salmon from other rivers.

Artificial Propagation After Construction of Grand Coulee Dam

Federal- and Washington-operated hatcheries other than the ones already described have also reared coho salmon on the mid-Columbia. These propagation activities are related to the development of hydroelectric power on the Columbia River and

started with the construction of Grand Coulee Dam. Rock Island, Bonneville, and Grand Coulee Dams began operation in 1933, 1938, and 1941, respectively, and were followed by additional dams (Fig. 1). All of these dams have had a detrimental and cumulative effect on runs of wild fish and returns from hatchery releases in the upper and mid-Columbia River.

Federal Hatcheries

Federal hatcheries were constructed near Leavenworth on Icicle Creek, a tributary of the Wenatchee River; near Entiat on the Entiat River; and near Winthrop on the Methow River. At the time the three hatcheries were designed, their projected total production was estimated at over 100 million salmon and steelhead juveniles. There were limiting deficiencies in the original plans, however, and production never reached this level (Fish and Hanavan, 1948). Leavenworth NFH was the center of the fish-culture operation. Following artificial spawning of the fish, eggs were incubated at Leavenworth NFH, and subsequently some of the eggs were shipped to Entiat NFH and Winthrop NFH for hatching, rearing, and release as fingerlings. Although there have been many changes over the years, Leavenworth NFH is still the largest, with a production capacity of about 2.5 million juveniles, followed by Winthrop NFH (1 million), and Entiat NFH (0.6 million). Currently, production at the hatcheries is almost exclusively devoted to spring chinook salmon in keeping with the goals of a comprehensive management plan for the mid-Columbia River (Mullan, footnote 1).

Leavenworth NFH is located about 500 miles from the ocean. Holding ponds for retaining adult fish prior to spawning were formed in a ¾-mile section of Icicle Creek bypassed by a diversion canal. Construction of four dams created three separate river-holding areas. Retrieval of fish was carried out by seining or various trapping schemes either in the holding areas or the tailrace of the bypass diversion canal dam.

Table 2.—Releases and returns of coho salmon reared at Leavenworth National Fish Hatchery (NFH).

Brood year	Egg source ¹	Area	Releases			Returns	
			Number	Date	Fish/lb.	Trapped	Obs./est.
1940	Rock Island ²	Icicle Creek	5,470	1942	11.4		
1941	Rock Island ²	Icicle Creek	11,050	1943	11.4	128	
1942	Lewis River	Icicle Creek	40,370	1943	91.0	4	
	Lewis River	Icicle Creek	69,627	1944	91.0		
1943	Lewis River	Icicle Creek	112,267	1944	91.0	1	
1944	Icicle Creek	Icicle Creek	133,703	1945	47.0	166	
	Lewis River	Icicle Creek	28,954	1945	24.8		
1945	Icicle Creek	Icicle Creek	1,896	1946	26.0		
1946			0			1	
1947	Icicle Creek	Icicle Creek	114,652	1948	60.2	22	
1948			0				
1949	Lewis River	Wenatchee River ³	229,969	Oct. 1950	27.6		
1950	Lewis River	Icicle Creek	98,786	1952	16.6	4	
	Icicle Creek	Icicle Creek	16,850	1952	16.6		
1951	Lewis River	Icicle Creek	47,607	1953	23.2	3	
1952	Lewis River	Icicle Creek	93,909	1954	42.4		
1953	Icicle Creek	Icicle Creek	2,419	1954	142.3		
1954	Quilcene	Icicle Creek	11,750	1955	50.0		
	Icicle Creek	Icicle Creek	3,222	1956	25.4		
	Quilcene	Icicle Creek	12,499	1956	38.0		
1955			0				
1956			0				
1957	Icicle Creek	Icicle Creek	2,884	Mar. 1959	27.7		
1958			0				
1959			0				
1960			0				
1961			0			15	150
1962	Eagle Creek	Icicle Creek	455,713	Aug. 1963	118.0		
1963	Eagle Creek	Icicle Creek	871,000	Oct. 1964	62.0	1,025	— ⁴
1964	Cascade	Icicle Creek	769,000	Sept. 1965	41.0	461	
	Cascade	Icicle Creek	656,000	March 1966	16.0		
1965 ⁵	Cascade	Wenatchee River	4,170,000	July-Sept. 1966	54.0	2,286	2,350
	Cascade	Icicle Creek	536,000	March 1967	19.2		
	Cascade	Snake River	708,000	April 1967	16.0		
1966	Little White Salmon	Icicle Creek	125,000	March 1968	23.0	12	
	Little White Salmon	Icicle Creek	550,000	March 1968	18.0		
	Little White Salmon	Snake River	700,000	April 1968	20.0		
	Little White Salmon	Wenatchee River	3,701,000	April 1967	150.0		
1967	Icicle Creek	Icicle Creek	26,000	April 1969	18.0	1,031	1,131 ⁶
	Little White Salmon	Wenatchee River	4,397,000	July 1968	412.0		
	Little White Salmon	Icicle Creek	727,000	April 1969	18.0		
	Little White Salmon	Snake Creek	102,000	May 1969	18.0		
1968	Icicle Creek	Icicle Creek	2,231,000	Sept. 1969	47.0	2,778	
	Little White Salmon	Icicle Creek	908,000	April 1970	16.0		
1969 ⁷	Willard & Icicle	Icicle Creek	1,457,000	March 1971	15.0	7	
1970	Unknown	Icicle Creek	1,102,000	March 1972	15.0	477	
1971	Icicle Creek	Icicle Creek	233,000	May 1972	313.0	67	
	Icicle Creek	Icicle Creek	341,000	May 1972	195.0		
	Icicle Creek	Icicle Creek	734,000	April 1973	18.0		
1972	Willard	Icicle Creek	156,000	April 1974	16.0		
	Eagle Creek	Snake River	645,000	April 1974	21.0		
1973	Eagle Creek	Icicle Creek	659,000	April 1975	5.0		
			Total		27,997,597		

¹Refers to either river of origin or hatchery located on river of origin as listed in Wahle and Smith (1979).

²From brood stock intercepted at Rock Island Dam.

³Stocked in Wenatchee River below Dryden Dam.

⁴5,000 jacks estimated.

⁵About 1,734,000 fry, progeny of Little White Salmon NFH stock, were released in Icicle Creek in March 1966; little if any survival was expected.

⁶100 Additional jacks estimated.

⁷About 2 million fry, progeny of Little White Salmon NFH stock, were released in Icicle Creek in March 1969; little if any survival was expected.

Entiat NFH and Winthrop NFH are located about 490 and 570 miles from the ocean, respectively. No provisions for holding adult fish were in the original plans for either hatchery. To remedy this deficiency, holding ponds connected to the rivers by short

fish ladders were constructed during World War II. In subsequent years these facilities were upgraded on a year-by-year basis, including construction of weirs to divert runs into the holding ponds.

Propagation of coho salmon at the

Table 3.—Releases of coho salmon reared at Entiat National Fishery Hatchery.

Brood year	Egg source	Releases			
		Area	Number	Date	Fish/lb.
1943	Lewis River	Entiat River	28,954	1944	91.0
1944	Lewis River	Entiat River	99,485	Oct. 1945	30.0
1963	Lower Columbia ¹	Entiat River	106,425	March 1965	29.0
1964	Lower Columbia	Entiat River	367,457	Sept. 1965	31.0
1965	Lower Columbia	Entiat River	275,000	June 1966	250.0
	Lower Columbia	Entiat River	299,855	Sept. 1966	52.0
1966	Lower Columbia	Entiat River	703,146	Oct. 1967	22.0
1967 ²	Lower Columbia	Entiat River	430,564	April 1968	644.0
	Lower Columbia	Entiat River	452,929	Oct. 1968	32.0
1968	Little White Salmon	Entiat River	588,745	July 1969	167.0
Total			3,352,560		

¹Lower Columbia River hatcheries are given in the annual report as the source of eggs; the specific source, however, is probably the same as the sources given for the same brood year at Leavenworth NFH (Table 2).

²About 1,672,000 fry were released in the Entiat River during April 1969; little if any survival was expected.

Table 4.—Releases of coho salmon reared at Winthrop National Fishery Hatchery.

Brood year	Egg source ¹	Releases			
		Area	Number	Date	Fish/lb.
1944	Carson	Methow River	40,082	Nov. 1945	91.0
1947	Methow River	Methow River	6,203	1949	24.0
1950	Methow River	Methow River	21,255	1952	20.0
	Lewis River	Methow River	149,578	1952	20.0
1951	Lewis River	Methow River	90,000	1953	15.0
1952	Lewis River	Methow River	94,514	1954	20.0
1953	Methow River	Methow River	6,840	1954	91.0
1954	Methow River	Methow River	1,493	1956	20.0
1958	Quilcene	Methow River	183,691	1959	19.0
1959	Eagle Creek	Methow River	638,039	Sept. 1960	28.0
1961	Eagle Creek	Methow River	327,653	1962	37.0
1962	Eagle Creek	Methow River	1,448,447	1963	44.0
1963	Big Creek	Methow River	824,045	1964	30.0
1964	Eagle Creek	Methow River	1,306,901	1965	40.0
1965 ²	Little White Salmon	Methow River	1,623,178	1966	58.0
1966 ³	Little White Salmon	Methow River	600,284	1967	48.0
1967 ⁴	Little White Salmon	Methow River	400,844	1968	24.0
1968	Little White Salmon	Methow River	113,778	1969	30.0
Total			7,876,825		

¹Refers to either river of origin or hatchery located on river of origin as listed in Wahle and Smith (1979).

²About 450,000 fry were released in the Methow River during 1965; little if any survival was expected.

³About 382,000 fry were released in the Methow River during 1966; little if any survival was expected.

⁴About 419,000 fry were released in the Methow River during 1967; little if any survival was expected.

three Federal hatcheries developed in two phases (Mullan, footnote 1). The first phase began with the completion of the hatcheries in the early 1940's. These hatcheries were a major component of a program of natural and artificial propagation envisioned in the Grand Coulee Fish-Maintenance Project (Fish and Hanavan, 1948). During this period, hatchery operations centered around sockeye and chinook salmon, and relatively few coho salmon were produced. In spite of bottlenecks in the facilities and other unanticipated problems, large numbers of fish were reared and released (Fish and Hanavan, 1948);

but, after a number of years it became apparent at all Columbia River Basin hatcheries that the survival of artificially propagated salmon and their contribution to the fisheries were not as large as had been expected.

The second phase of rearing coho salmon, which began in the early 1960's, was related to advances in fish culture, particularly in the areas of fish nutrition and feeding, and to a change in philosophy to raising fewer fish to a larger size (Wahle and Smith, 1979). During this period, the production of coho salmon greatly increased, and increases in the survival of hatchery fish and their contribution to the

fisheries were evident (Cleaver, 1969; Wahle and Smith, 1979).

This second phase of rearing coho salmon lasted until 1969 at Winthrop NFH and Entiat NFH, and until 1975 at Leavenworth NFH, when these hatcheries concentrated on rearing spring chinook salmon (Smith and Wahle, 1981).

About 28 million juvenile coho salmon, representing 26 brood years, were released from Leavenworth NFH from 1942 to 1975, primarily into the Wenatchee River system (Table 2). Over 3 million juveniles, representing 8 brood years, were released from the Entiat NFH into the Entiat River from 1944 to 1969 (Table 3). Slightly less than 8 million juvenile coho salmon, representing 17 brood years, were released from the Winthrop NFH into the Methow River from 1945 to 1969 (Table 4).

The coho salmon eggs used at the hatcheries were obtained from adults from many different spawning areas (Tables 2-4). The majority of juveniles released were progeny of lower Columbia River stocks because the upper and mid-Columbia stocks were too depleted to supply the hatcheries. Estimates of the abundance of these upper and mid-Columbia stocks can be obtained from examination of the number of adults migrating past dams downstream from the hatcheries on the main stem Columbia. In years 1933-39, for example, from 10 to 183 adult coho salmon were recorded annually passing Rock Island Dam at river mile 453 (Fig. 3). In 1940, 1941, and 1942, when the hatcheries became operational, coho salmon trapped at Rock Island Dam were 12, 29, and 1, respectively. Two females were spawned from the 12 taken in 1940; yielding a release of 5,740 juveniles from Leavenworth NFH into Icicle Creek in spring 1942. Six females were spawned from the 29 fish intercepted at Rock Island Dam in 1941, and the resulting 11,050 juveniles were released into Icicle Creek during the spring of 1943. The run in 1942 consisted of one fish and, in 1943, the 22 fish collected all died; consequently no eggs were taken in either year.

The first adult coho salmon from these efforts returned to Icicle Creek and Leavenworth NFH in 1944—125 3-year-olds and 3 jacks out of the (then) record run of 186 passing Rock Island Dam (Fig. 3). Although the 125 3-year-olds were not marked (the 3 jacks were marked fish of Lewis River stock released earlier in 1944), these fish were intuitively the adult returns of the 11,050 juveniles released in spring 1943, which were in turn the progeny of the 6 females spawned in 1941. Sixty-six females were spawned in 1944 yielding 203,093 eggs and ultimately 133,703 fingerlings that were released into Icicle Creek in 1945.

Subsequent returns to Leavenworth hatchery of later generations of mid- and upper Columbia River stocks were masked by coincidental releases of progeny of lower Columbia River stocks. For example, 166 coho salmon returned to Leavenworth in 1947, again out of a (then) record count of 229 at Rock Island Dam. These returnees are essentially attributable to 1945 releases of progeny of Icicle Creek and Lewis River stocks. From this collection of mixed stock returnees in 1947, 80 females were spawned, ultimately resulting in a release of 114,652 fingerlings in 1948.

There are indications that during this period the value of using indigenous stocks for reestablishing the runs was slowly being recognized (Mullan, footnote 1). The authors of the Leavenworth NFH annual reports state that coho salmon runs occurred every third year and that attempts to establish runs in the off years were unsuccessful. The 22 adult coho salmon noted as passing Rock Island Dam in 1943, after the initial interception and relocation phase of the Grand Coulee Fish-Maintenance Project was completed, were trapped for spawning purposes but died prior to use. Early run coho salmon passing Bonneville Dam were collected and held at the old Carson NFH for spawning, but these, too, died. The Washington Department of Fisheries (WDF) Director's initial offer of Lewis River coho salmon as a sub-

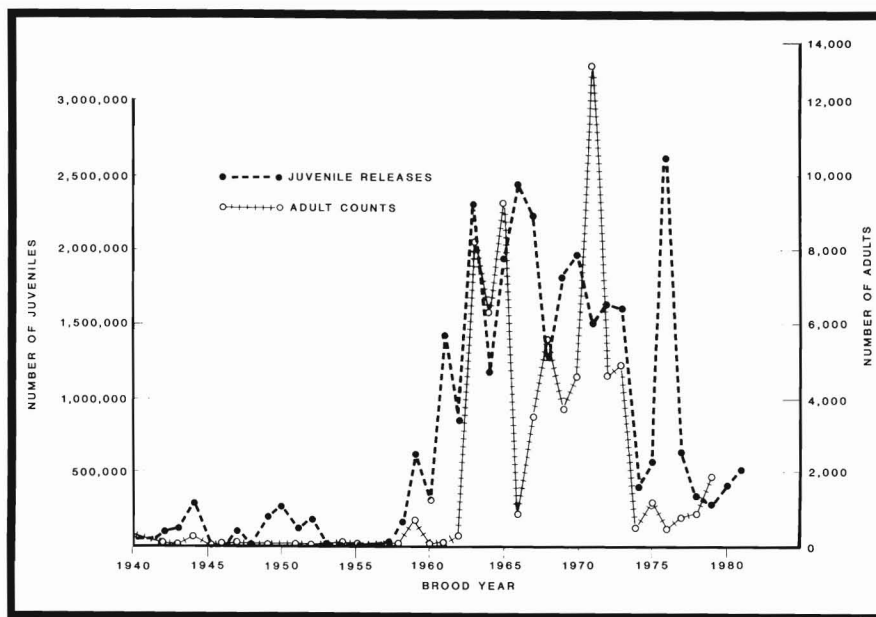


Figure 3.—Comparison of coho salmon adults counted at Rock Island Dam and juveniles released from mid-Columbia River hatcheries, brood years 1940-81.

stitute for indigenous stock was accepted with reluctance, Mullan (footnote 1) noted that in the 1942 annual report, District Supervisor Kemmerick, concerned about disease problems at the Leavenworth hatchery, wrote:

“The small lot of silver salmon fingerlings produced from eggs of two females spawned in the fall of 1940 were liberated on April 28 and never became affected with any disease. Likewise, the silver salmon fingerlings produced from the small lot of eggs taken in the fall of 1941 have outgrown any other fish on hand and have never required a treatment of any kind.”

The point to be emphasized here in relation to reestablishing the coho salmon runs by artificial propagation is the different rates of survival of indigenous and nonindigenous stocks, as documented by Ricker (1972). Coho salmon stocks, like most other anadromous salmonid stocks, have evolved over thousands of years to develop discrete populations, each with subtle life history differences, each homing to specific areas. The

ever increasing use of eggs from nonindigenous stocks that were not adaptable to the mid-Columbia probably led to lower rates of survival than were needed to develop viable runs of coho salmon.

The return of 125 adults in 1944 from the 1941 brood year release (11,050 juveniles) of indigenous stock, discussed previously, was good (1.13 percent). However, the lack of return from the smaller plant (5,740 juveniles) of the 1940 brood year created a problem in the establishment of a viable run. Low returns became even more of a problem in later years with increased releases of nonindigenous stock. Nevertheless, a tenuous relation does exist between annual coho salmon counts at Rock Island Dam, which rose from less than a few hundred fish in the 1940's to the thousands beginning in the mid-1960's, and the second phase of more numerous hatchery releases of juveniles beginning in the early 1960's (Fig. 3).

The number of adult coho salmon returning to Icicle Creek and Leavenworth NFH is shown in Table 2. This production has been reconstructed by Mullan (footnote 1) as follows:

1966—1,025 adults trapped, with another 5,000 jacks estimated; 1967—a good run estimated but only 461 collected due to washout of the trap; 1968—2,286 trapped out of an estimated total run of 2,350 fish; 1969—run largely blocked because of construction at John Day Dam in the lower Columbia River; 1970—1,031 trapped with about 100 adults and 100 jacks estimated remaining in Icicle Creek; 1971—2,778 trapped; 1972—some fish observed but only a few entered the trap (this was attributed to higher-than-normal stream flow); 1973—large number observed spawning in Icicle Creek but only 477 collected; and 1974—observations of a good run but trapping abandoned with only 67 fish collected incidental to the recovery of chinook salmon spawners.

The survival of hatchery propagated fish from the time of their release to the time of their return varies between brood years. Some information on the subject is available for Columbia River coho salmon in Wahle et al. (1974). Here, juvenile coho salmon of the 1965-66 broods were marked at 20 hatcheries, and survival rates back to the hatcheries were 0.9 percent for the 1965 brood and 0.7 percent for the 1966 brood. The rates at Leavenworth NFH were

lower than these averages. The return of fish to the mid-Columbia hatcheries, however, does not give the total picture of the success of their operation. For example, Fulton and Pearson (1981) reported good catches of marked coho salmon in the river fishery but no returns to Leavenworth NFH.

Entiat NFH released juvenile coho salmon in 1944-45 and 1965-69 (Table 3). There is no record of a return from these releases. The Entiat River, however, did not have a weir near the hatchery to trap and collect adult salmon during this period, and there is a possibility that adults did return to the river but migrated upstream past the hatchery.

Winthrop NFH released juvenile coho salmon in 1945, 1949, 1952-54, 1956, 1959-60, and 1962-69 (Table 4). The number of returning adults taken at the hatchery was by year: 1947, 41; 1950, 23; 1953, 6; 1954, 3; 1962, 250. The 250 adults taken in 1962 were a part of the record run at Rock Island Dam (Fig. 3); the 737 fish counted at the dam was the highest number of coho salmon observed in any previous year since the dam was completed in 1933. The years 1947, 1950, 1953, 1954, and 1962 were noteworthy at Winthrop NFH because a weir was used to trap and collect adult fish.

There are no records of coho salmon being taken in other years, but weirs were not used in those years and there is a possibility that adults did return to the river but migrated past the hatchery.

State Hatcheries

The WDF, in cooperation with the U.S. National Marine Fisheries Service (NMFS), started to rear salmon in the early 1960's near Pasco at Ringold Salmon Pond. The facility is a rearing pond, and, during the years 1963-72 and 1977-78, juvenile coho salmon were obtained from hatcheries on tributaries of the lower Columbia River and reared for release into the river above McNary Dam (Table 5). In later years, the facility concentrated on other species.

Propagation of salmon on the main stem of the mid-Columbia River was begun by the WDF and the PUD's of Chelan and Douglas Counties in the late 1960's to early 1970's (Table 6). Facilities were constructed 1 mile upstream of Rocky Reach Dam at Turtle Rock, adjacent to Priest Rapids Dam, and adjacent to Wells Dam. The three facilities were designed as spawning channels rather than conventional hatcheries. Coho salmon were only reared at Turtle Rock and Wells Dam. Initially, eggs

Table 5.—Releases of coho salmon reared at Ringold Salmon Pond.

Brood year	Releases		
	Number	Date	Fish/lb.
1962	35,000	Sept. 1963	31
1963	86,000	Dec. 1964	49
1964	161,000	Oct. 1965	141
1965	128,000	Oct. 1966	124
1966	None		
1967	322,000	Jan. 1969	15
1968	221,000	Mar. 1970	17
1969	264,000	Jan. 1971	13
1970	132,000	Feb. 1972	20
1971	None		
1972	None		
1973	None		
1974	None		
1975	None		
1976	1,029,000 ¹	Oct. 1977	31
1976	1,102,000	Mar. 1978	9
1977	None		
1978	None		
1979	None		
1980	None		
1981	None		
Total	3,480,000		

¹Released into the upper Yakima River system.

Table 6.—Number of coho salmon counted at Rocky Reach and Wells Dams and number of juveniles released from Rocky Reach (Turtle Rock) and Wells rearing facilities 1970-1983.

Year	Dam counts		Brood year	Number	Fish/lb.	Facility
	Rocky Reach	Wells				
1970	207	54	1967	190,000	26	Wells
1971	0	154	1968	54,000	25	Rocky Reach
1972	3,312	584	1969	100,000	25	Rocky Reach
1973	745	322	1970	736,000	9	Rocky Reach
1974	10,788	110	1971 ¹	393,000	13	Wells
			1971	388,000	15	Rocky Reach
1975	6,979	26	1972	276,000	15	Wells
			1972	572,000	14	Rocky Reach
1976	5,685	97	1973 ²	420,000	18	Wells
			1973	548,000	13	Rocky Reach
1977	927	70	1974	402,000	14	Rocky Reach
1978	1,438	73	1975	584,000	13	Rocky Reach
1979	244	63	1976	512,000	12	Rocky Reach
1980	713	77	1977	640,000	27	Rocky Reach
1981	522	19	1978	353,000	13	Rocky Reach
1982	882	337	1979	296,000	12	Rocky Reach
			1980	429,000	13	Rocky Reach
			1981	515,000	16	Rocky Reach
Total				7,408,000		

¹83,000 submigrants (104/lb.) released September 1972 into the Wenatchee River.

²504,000 submigrants (525/lb.) released July 1974 into Icicle Creek (Wenatchee River).

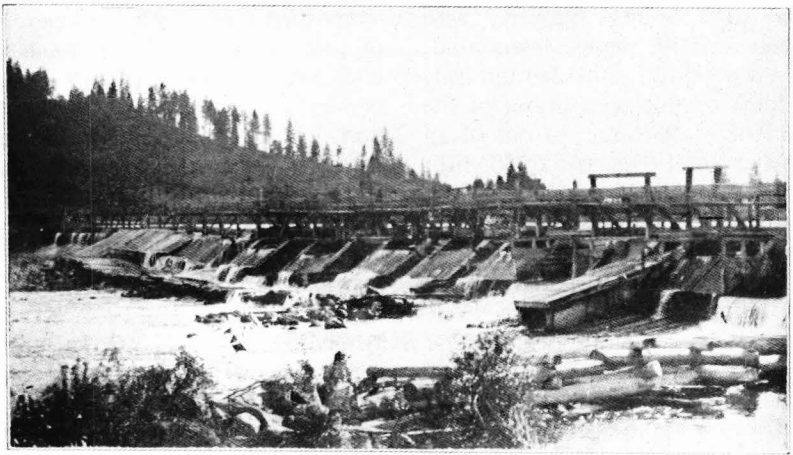
were hatched at Leavenworth NFH and transferred to the Wells Dam and Turtle Rock facilities for rearing, but in later years eggs or fry were obtained from hatcheries on the lower Columbia River. After some adjustments in rearing and release of relatively large juveniles, success was reflected in fish counts at dams, particularly the run of 10,788 tallied over Rocky Reach Dam in 1974 (Fig. 3).

Compared with the earlier Federal propagation activities using colder water, releases of large juveniles (Table 6) were made possible by the warmer Columbia River water at Wells Dam and Turtle Rock rearing facilities and may account for the subsequent higher number of adults at Rock Island Dam. Also, many of the small juveniles released from the Federal hatcheries were not regular production fish; they were reared from surplus eggs taken at lower Columbia River hatcheries and released at submigrant size. The release of large juveniles may also have influenced the age composition of returning adults. Although the age composition was never determined, PUD personnel observed that the runs were heavily weighted towards jacks, especially the large escapement of 10,788 passing Rocky Reach Dam in 1974 (Mullan, footnote 1).

Summary

There are five major river systems in the mid-Columbia region: The Entiat, Methow, Okanogan, Wenatchee, and Yakima. Prior to development of the region, all systems except the Okanogan River were known to have relatively large runs of coho salmon. These runs had probably been influenced by environmental abuses as early as the last half of the 19th century—as demonstrated in 1899 by the construction of salmon hatcheries to enhance the natural production of local stocks.

From 1899 to the time of the construction of the Grand Coulee Dam in 1941, the only hatcheries in the mid-Columbia were operated by the State of Washington and were on the Wenatchee and Methow Rivers. On the Wenatchee River, the first hatch-



Logging dam at Leavenworth, Wash., in about 1908. Cail Fishway is on the right; this type of fishway was not always an efficient passageway for salmon.

ery was constructed in 1899 upstream of Tumwater Canyon. This hatchery was closed in 1904 because of the lack of spring chinook salmon, which was considered the most valuable fish for propagation, and because of problems related to the harsh climate and isolated location of the facility. Reports indicate that some coho salmon were reared at the hatchery, but they do not give the extent of the production. The next, and last, hatchery on the Wenatchee during this period was built in the town of Leavenworth in 1913. This hatchery also had difficulty obtaining eggs of spring chinook salmon and was abandoned in 1931. Records, which are probably incomplete, show that 2 lots of coho salmon eggs were collected, 30,000 and 38,500, and 1 lot of 3.8 million fry was planted that was progeny of lower Columbia River stocks.

The first hatchery on the Methow River was constructed in 1899 at the confluence of the Methow and Twisp Rivers, producing mainly coho salmon. Its records of production are also incomplete, but we do know that from 1904 to 1914 almost 12 million coho salmon eggs were taken. The hatchery operation was moved in 1915, at which time a dam that did not have a fishway was constructed at Pateros near the mouth of the Methow River. The location of this hatchery was downstream of the dam,

and a total of 3.5 million coho salmon eggs were taken at the site from 1915 to 1920. The run of coho salmon declined, however, and no eggs were taken after 1920, although the hatchery continued to operate until 1931 with eggs and fry of other species.

In the 1930's the main stem of the Columbia began to be changed from a free flowing river to a chain of large reservoirs formed by hydroelectric dams. These dams and reservoirs had a detrimental effect on stocks of anadromous salmon and steelhead that had already been diminished through other environmental abuses and overfishing, and fish managers turned to artificial propagation to compensate for the loss of these valuable fish.

The next hatcheries were built by the Federal Government during the early 1940's after the construction of the Grand Coulee Dam which did not have a fishway. They were operated by the Interior Department's U.S. Fish and Wildlife Service, and were located near Leavenworth on Icicle Creek, a tributary of the Wenatchee River; near Entiat on the Entiat River; and near Winthrop on the Methow River. Leavenworth NFH was the largest facility, and from 1942 to 1975 it released, mainly into the Wenatchee River system, about 28.0 million juvenile coho salmon. A total of about 3.4 million juvenile coho

salmon were released from Entiat NFH into the Entiat River from 1944 to 1969, and about 7.9 million juveniles were released from Winthrop NFH into the Methow River from 1945 to 1969. Most of these fish were progeny of lower Columbia River stocks.

From the early 1940's to the early 1960's, the major emphasis at the Federal hatcheries was on rearing of sockeye and chinook salmon and not on coho salmon. In the early 1960's, however, the propagation of coho salmon greatly increased because of improvements in fish culture and the availability of large number of eggs from the lower Columbia region. Production of the species continued until 1969 at Winthrop NFH and Entiat NFH and until 1975 at Leavenworth NFH, at which times these hatcheries concentrated on the rearing of spring chinook salmon.

In the early 1960's, the State of Washington began to raise salmon and steelhead at a number of new facilities along the mid-Columbia River. The first facility to rear coho salmon was Ringold Salmon Pond near Pasco. Here, the WDF, in cooperation with the NMFS, released a total of about 3.5 million juvenile coho salmon into the river during the years 1963-72 and 1977-78. The stocks for the pond were obtained from hatcheries on tributaries of the lower Columbia.

In the late 1960's and early 1970's, the WDF, in cooperation with PUD's of Chelan and Douglas Counties, began to rear fish at three other facilities on the main stem of the mid-Columbia River. These facilities were designed as spawning channels rather than conventional hatcheries and were located at Turtle Rock, upstream of Rocky Reach Dam; at Priest Rapids Dam; and at Wells Dam. Coho salmon were only reared at Wells Dam and Turtle Rock facilities. A total of about 1.3 million juvenile coho salmon were released from the Wells Dam facility into the Columbia River from 1970 to 1976, and about 6.1 million that were reared at Turtle Rock were released from 1971 to 1983. Initially, eggs were hatched at

Leavenworth NFH and then transferred to the facilities for rearing; but in later years, eggs and fry were obtained from hatcheries on the lower Columbia River.

In summary, fishery agencies have operated salmon hatcheries in the mid-Columbia region for nearly a century; and, although their emphasis has been on the rearing of chinook and sockeye salmon, the total release of coho salmon has been tremendous. From 1899 to 1983, for example, hatchery records, which are incomplete, show that about 65.6 million juvenile coho salmon were released into the Columbia. The success of this hatchery operation is difficult to evaluate accurately. There is no doubt, however, that over the years many hundreds of thousands and perhaps millions of the adult coho salmon taken by fishermen off the Washington and Oregon coasts and in the Columbia River originated in the mid-Columbia hatcheries.

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