Appendix: Extended Summaries of Columbia Basin Supplementation Projects

Columbia Gorge Province
A 1. Hood River Winter-run Steelhead Supplementation

Background and History

The Hood River, Oregon, drains a 339 square mile watershed. Flowing northeasterly, it joins the Columbia River 22 miles upstream of the Bonneville Dam. There are 108 stream miles of accessible anadromous salmon and steelhead habitat in three major forks, the West, Middle, and East Fork Hood rivers. Spring-run and fall-run chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, coastal cutthroat (*O. clarki*), and summer-run and winter-run steelhead (*O. mykiss*) trout are present in the watershed. Native coho as well as spring-run and fall-run chinook salmon were extirpated from the subbasin, and both winter-run and summer-run steelhead are listed as Threatened under the Endangered Species Act (ESA). Coho and fall-run chinook salmon that are present in the watershed are primarily of stray hatchery origin. There are active artificial production programs to reintroduce spring-run chinook using Deschutes River stocks and to use supplementation in an attempt to rebuild the winter-run and summer-run steelhead populations. The winter-run steelhead supplementation program has been ongoing since1991 and is summarized here. The summer-run steelhead supplementation program has not produced sufficient year classes to warrant a summary.

Program Goals, Constraints, and Design

The goal of the Hood River Production Program's winter-run steelhead supplementation effort is to have 5,000 adult steelhead return to the Hood River watershed – 3,800 hatchery-origin adults and 1,200 natural-origin adults. If this return goal were to be met, 2,400 adults would be used for naturally spawning and production (1,200 natural-origin adults and 1,200 hatchery-origin adults) and 90 adults (45 males, 45 females) would be collected with the expectation of producing 85,000 hatchery-origin smolts for release; the remaining 2,510 adults would be available for harvest. Policy guidelines for the winter-run steelhead supplementation calls for 100% of the broodstock to be of natural-origin in the first generation of culture, 50% of natural-origin in the second generation, and 30% thereafter. Only 25% of the natural population can be collected for broodstock in any given run-year, and the naturally spawning population is supposed to include at least 50% natural-origin adults. To achieve this adult production, planning documents anticipated 85% pre-spawning adult survival, 65.5% egg-to-smolt survival, and 4.5% smolt-to-adult survival for artificially cultured steelhead. With 90 adults collected for broodstock and an adult return of 3,800 adults from hatchery origin estimated, 50 adult progeny were required to be produced by each spawning adult. Management controls on this project can be implemented by controlling access to spawning habitat. Spawning and rearing of steelhead in the Hood River is almost exclusively above Powerdale Dam at Hood River

RM 4. Anadromous fish must use a fish ladder at the dam, which facilitates controlling access to the spawning habitat above the dam.

Adult winter-run steelhead broodstock are collected in a trap at Powerdale Dam (Hood River RM 4) and held in ponds at the Parkdale Fish Facility (Middle Fork Hood River RM 3.5) until gametes are harvested. Fertilized eggs are incubated and juveniles reared at the Oak Springs Hatchery on the Deschutes River. Occasionally, juveniles also have been reared at Irrigon and Umatilla hatcheries on the Columbia River. Smolts are acclimated in ponds on the East Fork Hood River (RM 10) or at the Parkdale Fish Facility – Middle Fork Hood River (RM 3.5) before release. Because the abundance of natural winter-run steelhead was low throughout the late 1980's and 1990's an interim collection goal of 70 adults and production of 60,000 smolts was used to initiate the program.

Hatchery Culture

Although winter-run steelhead broodstock collections began in 1991, the first effective collection was in 1992. Based on five years of broodstock collection, hatchery rearing, smolt releases and adult returns, egg-to-smolt survival rates have ranged from 45% to 92%, averaging 68%. This average exceeds the master plan's 65.5% egg-to-smolt survival goal. Smolt-to-adult survival, however, has ranged from 0.3% to 1.3%, well below the 4.5% target set in the master plan. As a consequence the average number of adult progeny produced per adult used in the hatchery program has been only 8.6. Although this value is well below the recruit per spawner target of 50 set in the master plan to achieve the adult production goals, it is above replacement (R/S = 1.0). Table A1.1 summarizes the performance of the hatchery portion of the Hood River winter-run steelhead supplementation program

Table A1.1. Summary of the performance of hatchery-origin winter-run steelhead in the Hood River subbasin.

Brood Year	Eggs Incubated	Smolts Released	Egg to Smolt Survival	Hatchery-origin Recruits	Smolt to Adult Survival	Egg to Adult Survival
1992	53,308	48,985	92%	175	0.4%	0.3%
1993	62,150	38,034	61%	112	0.3%	0.2%
1994	95,043	42,860	45%	280	0.7%	0.3%
1995	63,793	50,896	80%	641	1.3%	1.0%
1996	85,467	59,837	70%	392	0.7%	0.5%

Integrated Natural and Artificial Production

Because winter- and summer-run races cannot be differentiated as juveniles, their survival during early life-stages of naturally produced steelhead are combined. Estimates have been made for egg-to-smolt and smolt-to-adult survival rates based on the abundance of natural-origin adult spawners alone, as well as total (natural-origin + hatchery-origin) adult spawner abundance (Table A1.2.). Naturally spawned egg-to-smolt survival rates range from 0.3% to 1.7%, averaging 1.2%. Naturally produced smolt-to-adult survival rates range from 2.8% to 5.5%, averaging 3.8%.

Table A1.2. Estimated life-stage survival of natural-origin steelhead in the Hood River subbasin.

Brood Year		Adults	Females[2]	Eggs[3]	Smolts	Egg to Smolt Survival	Adult Recruits	Smolt to Adult Survival	Egg to Adult Survival
1994	Natural	1,114	668	2.3 M	8,600	0.4%	472	5.5%	0.02%
	Total[1]	1,567	940	3.3 M		0.3%			0.01%
1995	Natural	275	165	577 K	9,800	1.7%	308	3.1%	0.05%
	Total	1,702	1,021	3.6 M		0.3%			0.01%
1996	Natural	520	312	1.1 M	15,400	1.4%	434	2.8%	0.04%
	Total	2,157	1,294	4.5 M		0.3%			0.01%

5. Includes both natural-origin and hatchery-origin spawning adults
6. Using an estimate of 60% females
7. Using an estimate of 3,500 eggs per

Smolt-to-adult survival for the hatchery-origin smolts has not met the program target (4.5%) and is lower than the smolt-to-adult survival of naturally produced smolts. Because egg -to-smolt survival in the hatchery is high, however, the number of adult recruits per spawner for the hatchery component exceeds those for the natural component (Table A1.3).

Table A1.3. Estimated Recruits per spawner (adult progeny per parent) for hatchery spawning (Ra) and natural spawning (Rw) Hood River winter-run steelhead.

	Natural Steelhead			Hatchery Steelhead			
Brood Year	No. of Spawners	No. of Recruits	Recruits/ Spawner	No. of Spawners	No. of Recruits	Recruits/ Spawner	H:N Advantage
1991/92				39	93	2.38	
1992/93	354	293	0.83	36	351	9.75	11.74
1993/94	306	211	0.69	54	643	11.91	17.26
1994/95	166	218	1.31	37	367	9.92	7.57

From 1991/92 through 1999/2000 the winter-run steelhead integrated hatchery – natural supplementation program produced an average of 725 adult winter-run steelhead (range = 317 in 1994/95 to 1,227 in1999/2000) (Figure A1.1). The percentage of hatchery-origin adults in the adult winter-run steelhead arriving at Powerdale Dam ranged from 24.3%

(1999/2000) to 68.9% (1996/97), averaging 44%. Prior to initiating the winter-run steelhead supplementation program, a more conventional steelhead hatchery program was ongoing in the Hood River. As late as 1991/92 Big Creek stock steelhead adults were returning to the watershed and being passed above Powerdale Dam. In 1991/92 this stock represented 31% of the winter-run steelhead passed above the dam. From 1992/93 through 1994/95 the percentage of hatchery steelhead passed above the dam was less than 5% because adults had not yet started returning from the supplementation program. After adults from the supplementation program began returning, the annual percentage of hatchery winter-run steelhead that were passed above the dam to have the opportunity to spawn naturally have been 43% (1995/96), 52% (1996/97), and 48% (1997/98). These percentages are within the guidelines established for the program.

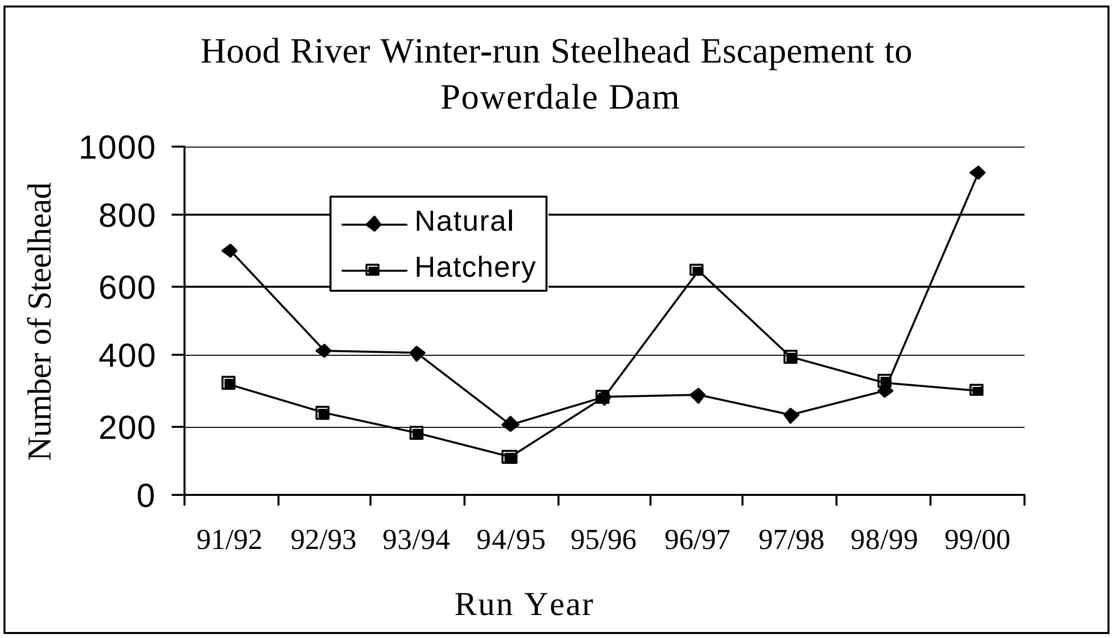

Figure A1.1. Adult winter-steelhead counts at Powerdale Dam.

This summary was based on information from O' Toole (1992), Coccoli (2000), Olsen and French (2000), and Kostow et al. (2000).

Columbia Plateau Province

A 2. Umatilla River Summer-run Steelhead Supplementation

Background and History

The Umatilla River, Oregon, drains a 2,290 square mile watershed. The river originates in the Blue Mountains, flows northwest, and joins the Columbia River at river mile (RM) 289, below McNary Dam. Spring- and fall-run chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon, as well as summer-run steelhead (*Oncorhynchus mykiss*) are present in the subbasin. The spring- and fall-run chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon were extirpated from the subbasin in the early 1990's. Summer-run steelhead are native to the subbasin. There are active artificial production programs to reintroduce spring- and fall-run chinook and coho salmon, and to use supplementation to provide harvest opportunities and increase the numbers of spawning adult summer-run steelhead. Of the 770 miles of stream in the watershed, 233 are believed to be suitable for rearing steelhead juveniles. Hatchery-origin summer-run steelhead have been released into the Umatilla River since 1967. Out-of-basin Skamania and Oxbow stocks were released from 1967 - 1970. Umatilla River stock, reared at either Oak Springs Hatchery on the Deschutes River or at the Umatilla Hatchery on the Columbia River, has been released since 1981. Performance of the summer-run steelhead supplementation program is summarized here.

Program Goals, Constraints, and Design

The goal of the Umatilla River summer-run steelhead supplementation program is to return 5,500 adult steelhead to the mouth of the Umatilla River – 1,500 hatchery-origin adults and 4000 natural-origin adults. Of those adults, 4,000 would be used for natural spawning and 116 adults would be used to produce 150,000 hatchery-origin smolts for release leaving 1,384 adults available for harvest. Policy guidelines for the summer-run steelhead supplementation program calls for 88% of the hatchery broodstock to be of natural-origin. The naturally spawning population is to include at least 50% natural-origin adults. To achieve this adult production planning documents anticipate 65.5% egg-to-smolt survival, and 2.7% smolt-to-adult survival for artificially cultured steelhead.

Adult summer-run steelhead broodstock are collected in a trap at Three Mile Falls Dam (Umatilla River RM 4) and held in ponds at Minthorn Springs (Umatilla River RM 64) where their gametes are harvested. Eggs are incubated and juveniles reared at the Umatilla Hatchery on the Columbia River. Smolts are acclimated in ponds at Minthorn Springs and Bonifer Ponds before release. The Bonifer facility discharges into Boston Canyon Creek and then into Meacham Creek (Meacham RM 2). Meachan Creek joins the Umatilla River at RM 79.

Hatchery Culture

Based on data from six years of broodstock collection, hatchery rearing, smolt releases and adult returns, hatchery egg-to-smolt survival rates have ranged from 43.3% to 66.6%, averaging 60%. This rate is somewhat under the master plan's goal of 65.5%. Smolt-to-adult survival has ranged from 0.08% to 0.91%, averaging 0.40%, a value well below the 2.7% target set in the master plan. Adult-to-adult production for the hatchery portion of the program, calculated for the 1985 through 1992 production years has averaged 2.86 (range 2.07 to 4.69, n = 8). Table A2.1 summarizes the performance of the hatchery portion of the Umatilla River summer-run steelhead supplementation program.

Table A2.1. Summary of the performance of hatchery-origin summer-run steelhead in the Umatilla River subbasin.

Brood Year	Eggs Incubated	Smolts Released	Egg to Smolt Survival	Estimate of Adult Escapement	Smolt to Adult Survival
1991	340,674	199,404	66.6%[1]	141	0.08%
1992	423,810	158,268	43.3%[2]	613	0.43%
1993	255,000	153,098	60.0%	593	0.39%
1994	234,000	146,463	63.1%	1344	0.91%
1995	223,525	146,703	65.6%	270	0.19%
1996	224,000	137,287	61.3%	NA	NA

1. Survival estimate does not include smolts used in passage evaluation or graded and removed.
2. Survival estimate does not include alevins destroyed because of a reduction in program goals.

Integrated Natural-Artificial Production

Survival estimates for early life-stages of naturally produced steelhead are unavailable. Adult-to-adult survival of naturally produced steelhead (a combination of natural spawning by both hatchery-origin and natural-origin adults) for the 1985 to 1992 brood years averaged 0.60 (range 0.43 to 1.70).

From 1987/88 through 1999/00 the integrated natural- artificial supplementation program for summer-run steelhead produced an average of 2,025 returning adults (range = 1,111 in 1990/91 to 2,892 in 1999/00) (Figure A2 1). The percentage of hatchery-origin adults in the adult summer-run steelhead arriving at Three Mile Falls Dam averaged 31%, ranging from 7% (1987/88) to 59% (1996/97). The proportion of hatchery-origin steelhead passed above the dam to have the opportunity to spawn naturally has been equivalent each year to the proportion arriving at the dam. These annual proportions are within the guidelines established for the program. Over this time period annual harvest within the subbasin averaged 171 natural and 96 hatchery-origin steelhead. In addition, sport and net fisheries in the Columbia River averaged 51 and 64 Umatilla steelhead, respectively.

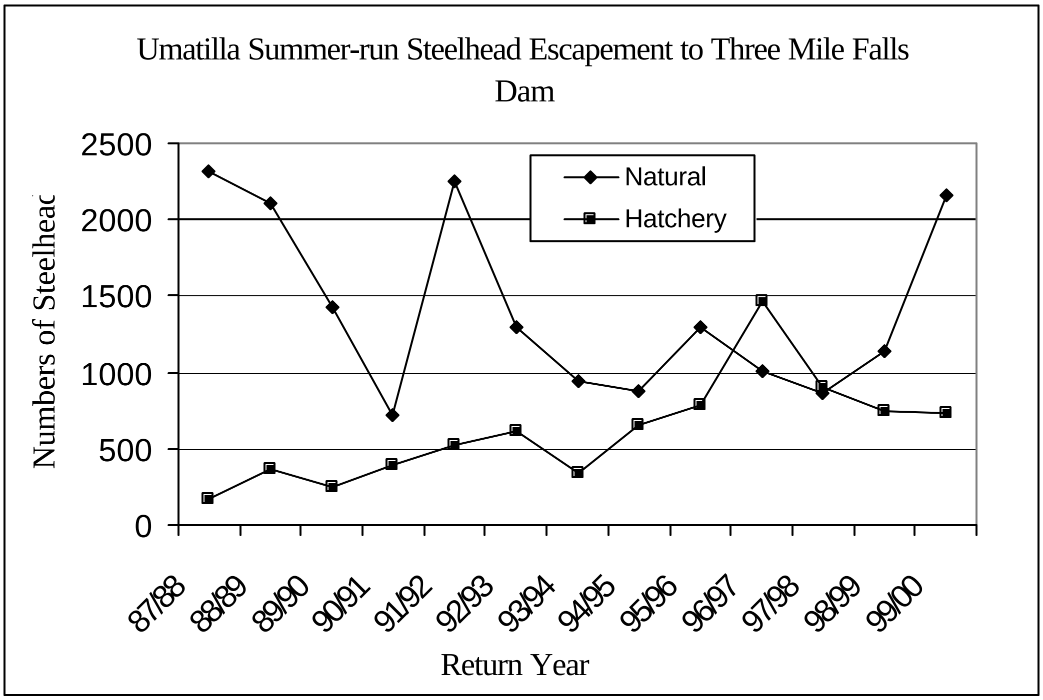

Figure A2.1. Adult summer-steelhead counts at Three Mile Falls Dam.

The Umatilla subbasin summary (Saul 2001) and Umatilla hatchery monitoring and evaluation (Hayes et al. 1997) conclude that without improvement in the smolt-to-adult survival rates the steelhead supplementation program is unlikely to meet its target production.

This summary was based on information taken from Hayes et al. (1997), James (2000), Phillips et al. (2000), and Saul (2001).

Columbia Cascade Province

A 3. Wenatchee River - Chiwawa Spring-run Chinook Supplementation

Background and History

The Wenatchee River, Washington, drains a 1,371 square mile watershed with 230 miles of major streams and rivers. Draining a portion of the east Cascade Mountains in north central Washington, the Wenatchee River joins the Columbia River at river mile (RM) 468. There are several significant tributaries. The Little Wenatchee and White Rivers flow into Lake Wenatchee, the source of the river. Nason Creek and the Chiwawa River are tributaries just below Lake Wenatchee. Icicle and Chumstick Creeks join the river near Leavenworth, Washington. Mission and Peshastin Creeks join the mainstem river in the lower subbasin.

Spring- and summer-run chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), and summer-run steelhead (*Oncorhynchus mykiss*) are present in the Wenatchee subbasin. Coho salmon (*Oncorynhcus kisutch*) were historically abundant, but were extirpated in the early 1900s. Spring-run chinook salmon and summer-run steelhead are listed as endangered under the ESA, while summer-run chinook and sockeye salmon are not.

Several artificial production programs operate in the subbasin. Leavenworth National Fish Hatchery annually produces 1.625 million unlisted "Carson" spring-run chinook salmon for the Grand Coulee Fish Maintenance Project (established in 1937) to support fisheries. The Chelan County PUD Rock Island Fish Hatchery Complex's program produces spring- and summer-run chinook and sockeye salmon smolts. There is a Yakima Nation coho reintroduction program underway that relies on the transfer of lower Columbia River coho stocks. Currently in a feasibility assessment phase, the project utilizes hatchery facilities associated with the Leavenworth NFH Complex and the Rock Island Fish Hatchery Complex, as well as natural acclimation sites. The Chiwawa spring-run chinook salmon supplementation program that began in 1989 is summarized here.

Program Goals, Constraints, and Design

The production goal, developed by the Mid-Columbia Hatchery Program (BAMP 1998) and part of the Rock Island Project Settlement Agreement (RIPSA 1999), is to collect 400 adult spring-run chinook salmon and release 672,000 yearling smolts. No explicit numerical goals for adult salmon of hatchery or natural-origin to either the subbasin, or specific tributaries, are evident. Planning documents, however, did call for adult collections to be from naturally produced adults only, and in a 1:1 sex ratio. Part of the run (30%) could be collected at a weir operated five out of six days. One of every three naturally produced adults could be retained as broodstock. Each year a minimum of 80 individuals are required to be available for natural spawning to trigger beginning the supplementation production. BAMP (1998) set 95% pre-spawning adult survival and 86% egg to release survival goals for the hatchery production. SAR's were not explicit, but a 0.30% SAR is typical for spring-run chinook from mid-Columbia River hatcheries. The Little Wenatchee River is established as an unsupplemented reference population.

The Chiwawa spring-run chinook program traps returning adults at a weir constructed in the Chiwawa River at the Chiwawa acclimation site. Adults are transported to Eastbank Fish Hatchery and then spawned when sexually mature. Eggs are incubated throughout the winter, and the resultant progeny are reared in ponds at Eastbank Fish Hatchery. The juveniles are held at the Eastbank Fish Hatchery until they are large enough to have coded wire tags inserted and their adipose fins clipped. In October the fish are then transferred to the Chiwawa acclimation site where they are held until April of the following year and subsequently released as yearling smolts. Enumeration of returning adults takes place in a fish ladder at Tumwater Dam and during spawning ground surveys.

Hatchery Culture

Fish production for the Wenatchee-Chiwawa spring-run chinook program began in 1989, and the first yearling smolt releases were in 1991. Life-stage survival of adults and progeny meet program performance standards (Table A3.1). Because low adult returns and low trap efficiency have limited adult collections, hatchery-origin adults have been bred with natural-origin adults. Even using hatchery-origin adults to supply additional gametes, production has remained below program goals, with an average annual production of 77,400 smolts released.

Table A3.1. Life stage survival of spring-run chinook cultured for the Chiwawa supplementation project.[1]

Year	Adult - Female to spawning	Egg Incubation	Fry Rearing	Total - Egg to Release
2000	100.0	89	89	85.0
Multi-year Average	97.7			84.5
Standard	78.4			86.0

1. WDFW 2002; BAMP 1998

Table A3.2. Characteristics of the Chiwawa spring-run chinook salmon supplementation project[1]. Number of juvenile released into the Chiwawa River, adults produced, and survival rates for 1989-1995 broods.

Brood Year	Release Year	Number Released	Adults Produced	% Adult Survival
1989	1991	43,000	206	0.479
1990	1992	53,170	19	0.036
1991	1993	62,138	35	0.056
1992	1994	85,113	33	0.039
1993	1995	223,610	286	0.126
1994	1996	27,226	23	0.084
1995	1997	No Hatchery Program		
1996	1998	15,176	66[2]	0.435
1997	1999	266,148	2269[2]	0.853
1998	2000	75,906	34[2]	0.005
1999	2001	No Hatchery Program		

1. Table taken from Ford, M. 2002. 2. Incomplete adult returns

Integrated Natural-Artificial Production

Natural spring-run chinook emigrant-to-adult survival estimates for the Chiwawa River have ranged from 0.05% - 1.5% whereas Chiwawa River hatchery smolt-to-adult survival has been less, ranging from 0.03% - 0.48%. Estimates of adult-to-adult replacement rates for hatchery and natural production (Ra and Rw) is not yet available. Natural- and hatchery-origin adult returns are estimated from redd counts and carcass surveys throughout the subbasin, and direct counts at Tumwater Dam. Adult abundance varies appreciably. Fewer than 100 adults were believed to have returned to the subbasin in 1995. In 2001 adult numbers were estimated at 6,268. Hatchery-origin adults have averaged 40% of the return since 1993 (Figure A3.1). The increased returns observed in 2000 and 2001 are believed to be the result of improved outmigration conditions and improved ocean survival.

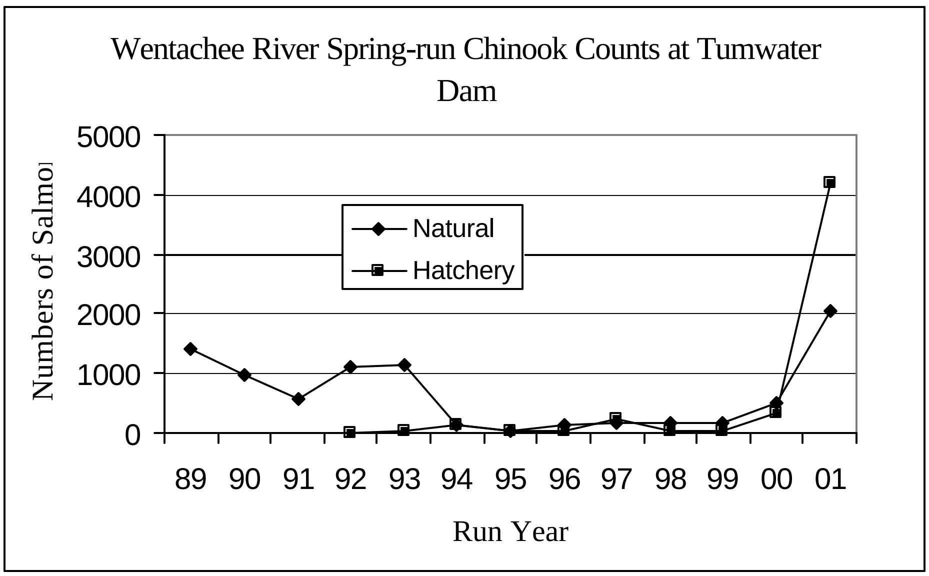

Figure A3.1. Adult spring-run chinook counts at Tumwater Dam.

Redd counts from the Chiwawa River and the Little Wenatchee River provides a contrast in abundance trends in a supplemented versus an unsupplemented tributary. The ratio of redds in Chiwawa River vs. the Little Wenatchee River does not exhibit any evident trend (Figure A3.2). An upward trend in the ratio of the number of redds from the Chiwawa River (supplemented) to the number of redds from the Little Wenatchee River (unsupplemented) would be expected if hatchery-origin adults were adding natural-origin adults in subsequent year classes.

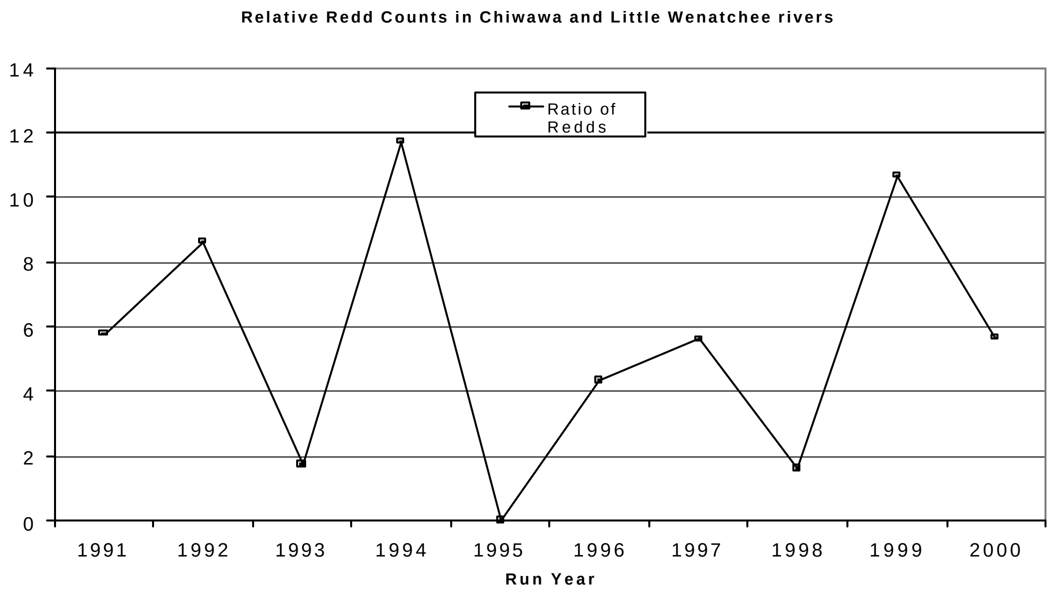

Figure A3.2. Relative number of redds in the supplemented Chiwawa River and the unsupplemented Little Wenatchee River. The number of redds was taken from NMFS (2002). Chiwawa River redds counts were adjusted to account for the proportion of hatchery-origin adults present.

This summary was based on information reported in BAMP (1998), Ford (2002), NOAA-Fisheries (2002) and WDFW (2002).

Columbia Cascade Province

A 4. Okanogan/Similkameen River Summer-run Chinook Salmon Supplementation

Background and History

The Okanogan River originates in British Columbia and flows south through a series of six large lakes before reaching the United States border where it enters Washington State. The basin covers approximately 8,200 square miles, with 2,500 square miles in the United States. The river joins the Columbia River at river mile (RM) 533.5, between Chief Joseph and Wells dams. The Okanogan River is the northernmost geologic dividing line between the Cascade and Rocky Mountain ranges. The Similkameen River is a primary tributary of the Okanogan River, contributing up to 75 percent of the total flow.

The Okanogan Watershed currently supports anadromous runs of summer-run chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), and steelhead trout (*Oncorhyncus mykiss*). Spring-run chinook have been extirpated from the Okanogan subbasin. Although the historical record of steelhead trout in the Okanogan subbasin is incomplete, it is likely that very few ever used the Okanogan River. Salmon Creek, Omak Creek, and the Similkameen River supported small runs, but these were eliminated or reduced by passage barriers and few wild steelhead currently spawn successfully in the Okanogan Basin because many of the tributaries with acceptable potential spawning habitat are dewatered during the summer months.

Artificial production programs for summer-run chinook salmon, sockeye salmon and summer-run steelhead have released juvenile anadromous salmonids into the Similkameen and Okanagon Rivers and their tributaries since 1983. The Cassimer Bar Hatchery on the Columbia River was used to produce sockeye salmon until 2001 when the Douglas PUD discontinued funding to that facility. This section describes the Okanogan/Similkameen summer-run chinook supplementation program

The Washington Department of Fish and Wildlife, under contract from the Chelan County Public Utilities District #1, operates the Okanogan/Similkameen summer-run chinook supplementation program. This program partially compensates for fish losses from Wells and Rock Island dams on the mainstem Columbia River operated by the PUD, but operates in addition to the other salmon and steelhead production facilities operated primarily for dam compensation. The program is designed to assist historically depressed wild stocks.

Program Goals, Constraints, and Design

The Okanogan/Similkameen summer-run chinook supplementation program now consists of two major components, a hatchery spawning and rearing project, and a spawning ground survey project. The WDFW evaluates this program and provides annual reports of broodstock management, fish spawning and rearing in the hatchery and rearing ponds, and natural spawning in nearby waters. We obtained annual reports for the hatchery program for 1989-2000 and spawning-ground survey reports for 1999-2001 (with tabulated data from 1956). There is no control or reference stream with which to compare these figures.

Adult summer-run chinook are collected for broodstock in a trap in the east fish ladder at Wells Dam. The captured adults are transferred to Eastbank Fish Hatchery where they are held until maturity and then spawned. Egg incubation and initial fry rearing is conducted at Eastbank Fish Hatchery. In October each year 600,000subyearling summer-run chinook are transferred to the Similkameen Pond. The summer-run chinook are volitionally released from the pond site the following April-May.

Broodstock collection is intended to sample a representative portion of the run of summer-run chinook passing Wells dam to the upper Columbia River tributaries (Methow and Okanogan rivers). Adult collections are targeted to represent the fish in 80% of the run but to collect no more than 20% of those fish (based on fish counts at Rocky Reach Dam downstream) and to collect jacks in proportion to their representation in the whole run. Guidelines for the proportion of hatchery- and natural-origin salmon in the hatchery and natural spawning components were not specified in the documents we reviewed. Escapement to natural spawning grounds had precedence over collection of broodstock for artificial propagation during years when escapement to the basin was under 40% of the ten-year average. The spawning ground surveys of the Methow, Okanogan, and Similkameen rivers have been used to evaluate where the supplemented wild/hatchery fish are spawning in relation to the rearing ponds. Comprehensive ground surveys and weekly aerial surveys were used to obtain the numbers of redds. Carcasses were assayed for origin (hatchery or wild).

Hatchery Culture

Broodstock Management. Broodstock management has evolved in the period for which we reviewed annual reports. The project was originally envisioned to use primarily wild fish for spawning to limit the generations in the hatchery environment. Depressed runs made this goal problematic; the adult collections for hatchery production also needed to minimize impacts to the upstream migrating summer chinook, Okanogan sockeye, as well as ESA endangered summer steelhead. Adults were initially collected from the west (right bank) fish ladder and from voluntary returns to the Wells Fish Hatchery. Both of these adult collections were skewed toward later arrival times when compared to all the fish counted passing over Wells Dam. Since 1993 brood collection has been conducted only at the east fish ladder trap and has been spread out over a period representing the 10-year average passage time. In the initial plans, up to 30% of the adult run to Wells Dam could be collected unless that meant taking more than 40% of the total run (percentages based on fish passage at downstream Rocky Reach Dam). Whenever collections had to stop at the dam, the target number would be achieved by fish collected from the voluntary returns to Wells Fish Hatchery. Since 1994, the target number has been reduced to 20% of the run, and since 1996 only fish collected at the dam have been used (discontinued use of Wells Hatchery volunteers).

Since 1995, numbers of fish actually spawned in the hatchery ranged from 372 to 513 (both sexes), with no trend. Fecundity was recorded beginning in 1996; there is no trend through 2000, with a fecundity of 5,000 eggs/female. The salmon trapped at the Wells Dam east fish ladder have been a mixture of natural- and hatchery-origin adults and the hatchery-origin component is a mixture of mid-Columbia River Basin stocks. Based on coded-wire tags returns the percentage of known hatchery-origin fish in the collections appears to have increased from 36% in 1995 to 67% in 2000 (with much variation). Of the hatchery-derived fish, the Similkameen Pond yielded the largest percentage of the returning adults but hatchery fish from other sources were always represented (Carlton Pond; Wells, Turtle Rock, Wenatchee hatcheries). There is no information on whether the unmarked adults collected were wild fish, natural progeny of hatchery fish that spawned in the wild, or unmarked hatchery-origin fish.

Juvenile Rearing. Life-stage survival in the hatchery has met program expectations and is within the accepted fish culture performance standards (Table A4.1).

Table A4.1. Hatchery performance of Similkameen summer-run chinook salmon.

Percent	Brood Year											
Survival	‘89	‘90	‘91	‘92	‘93	‘94	‘95	‘96	‘97	‘98	‘99	‘00
Adult	92	96	92	95	86	85	90	94	91	74	98	95
Egg	90	85	88	87	83	87	83	83	85	53	90	88
Fry	97	97	97	98	99	73	93	87	97	98	97	98
Smolt	57	99	97	93	90	99	98	93	99	98	99	97
Overall	50	81	83	79	75	63	75	67	82	51	86	83

With the exception of 1991 and 2000, smolt releases have approximately met the target of 570,000 (Figure A4.1).

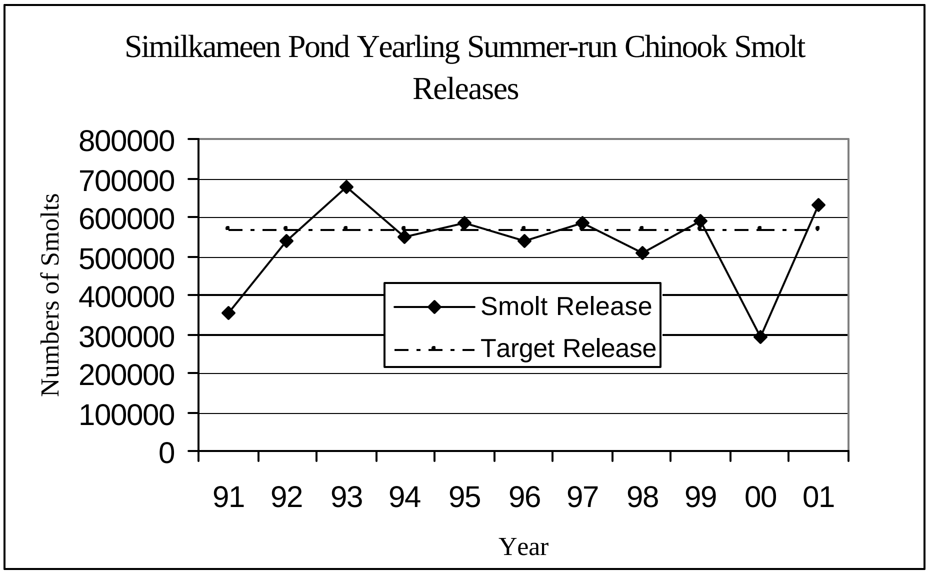

Figure A4.1. Yearling summer-run smolt releases from the Similkameen Ponds.

Unfortunately, smolt-to-adult-return (SARs) rates from hatchery production from Eastbank Fish Hatchery are not available.

Integrated Natural-Artificial Production

Spawning ground surveys have been conducted in the Similkameen (by air since 1957 and ground since 1989) and Okanogan (aerial since 1956 and ground since 1990). Redd-count data are available for most of those years, and show a great deal of variability with highest numbers generally in 2000 and 2001. These surveys indicated that spawning was concentrated in the vicinities of the rearing ponds, causing redd superposition in these areas and underutilization of sites farther removed from the rearing ponds. Recovered carcasses indicated that there was a fairly high percentage of hatchery-derived spawners (in 2000 49% on the Okanogan River, and 73.7% on the Similkameen River). Although there was no yearly trend for the Okanogan, the Similkameen showed an increase in percentage of hatchery fish over time (51.6% in 1988, 60.3 in 1999, and 73.7 in 2000). Three years of records, however, is insufficient for much confidence. In addition, the trend in redd counts from the aerial surveys on the Okanogan and Similkameen rivers shows that counts are higher in the later 1990s than in the previous decade (Figure A4.2).

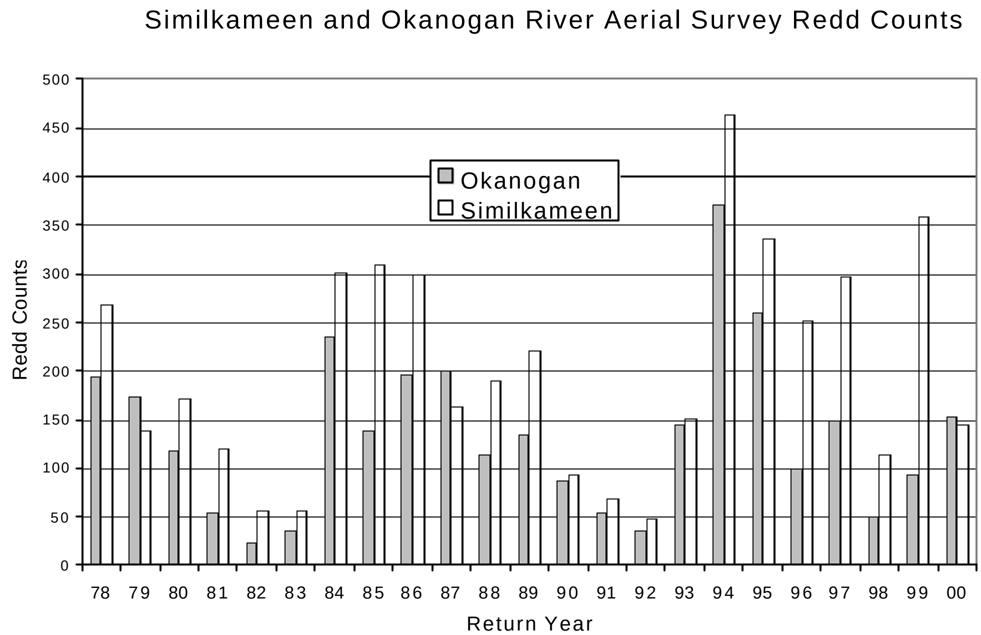

Figure A4.2. Redd counts from aerial surveys of the Okanogan and Similkameen river basins. Redd counts for ’98, ’99, and ’00 were decreased to by the proportion of hatchery carcasses identified during ground surveys.

To date no estimates of natural juvenile production has been made available. SARs are unavailable for hatchery or natural production. Adult recruits per spawner for the hatchery and natural component have also not been estimated. Consequently, there is no basis for assessing the integrated natural and artificial production in this program. The redd count data might suggest that abundance is higher from the 1994 through 1997 run years in the Okanogan and Similkameen Rivers (and also 1999 in the Similkameen River). Figure A4.2 was constructed to present potential abundance of natural spawning salmon. In it the reported counts from the aerial surveys were adjusted downward in 1998, 1999, and 2000 to reflect the proportion of hatchery salmon carcasses identified during ground surveys. Adult broodstock collections at Wells Dam identified returning hatchery fish as early as 1993. It is likely that the redd counts from the early to mid 1990s include a substantial proportion of hatchery-origin fish that are not sufficiently accounted.

Survival: Current evidence from percentages of wild and CWT-marked hatchery adults in collections suggests that the hatchery fish are gaining numbers over wild fish, perhaps an indication of better relative survival. The numbers of smolts from in-river spawnings, however, is not known, and so cannot serve as a basis for survival comparisons. Smolt to adult survival of the hatchery fish need to be calculated for each pond in each of the later years to establish if there is a trend, assuming the adult collections are an adequate sampling of the run. Age structure of the broodstock collections is also estimated annually, which could be used as the basis for evaluating age-related survival or shifts in the age structure of spawners.

Fecundity: Fecundity of females spawned in the hatchery has been calculated since 1996, and shows no change.
Spawning distribution: In-river spawning distribution is unnaturally clumped near rearing ponds, something the program seeks to alleviate by building another pond on the Okanogan River.
Spawning ratio: Data on the ratio of supplemented to natural spawners obtained for three years suggest no change for the Okanogan, but a shift toward more hatchery-derived spawners in the Similkameen.

In conclusion, the Okanogan/Similkameen summer-run chinook supplementation program has the potential to contribute to an experiment to test the efficacy of supplementation, but does not include a reference or methods in place to adequately sample the non-hatchery component of the juvenile production. For this program to contribute to an evaluation of supplementation, the estimation of Ra and Rw, are needed. No assessment can be made with the available data.

This summary was based on information reported in Peven (2000), BAMP (1998), Tonseth (2002), Miller (2002), Tonseth et al. (2002a, b, c, d), Petersen et al. (1999a, and b), Petersen et al. (1997), Eltrich et al. (1994a, 1994b, 1995), Murdoch and Miller (2000) and Murdoch et al. (2001)

Blue Mountain Province

A 5. Imnaha summer-run Steelhead Supplementation Program

Background and History

The Imnaha River watershed drains approximately 980 square miles in northeastern Oregon, joining the Snake River at river mile (RM) 191.7, above Lower Granite Dam. The mainstem Imnaha extends approximately 63.5 miles upstream from the Snake River confluence to the North and South Forks in the Eagle Cap Wilderness. Primary tributaries, beginning at the confluence with the Snake River, include Cow Creek, Lightning Creek, Horse Creek, Big Sheep Creek, Freezeout Creek, Grouse Creek, Summit Creek, Crazyman Creek, Gumboot Creek, Dry Creek, Skookum Creek, South Fork, Middle Fork, and North Fork Imnaha River. Approximately 398 river miles of anadromous salmonid spawning and rearing habitat have been identified in the Imnaha subbasin. Spring- and fall-run chinook salmon (*Oncorhynchus tshawytscha*), and summer-run steelhead trout (*O. mykiss*) occur in the watershed. Native fall-run chinook salmon are nearly absent from the subbasin. Anecdotal accounts suggest that fall chinook may have historically used the lower 19.5 miles of the Imnaha mainstem for spawning, but likely did not occur above the town of Imnaha. The summer-run steelhead and spring-run chinook are listed as Threatened under the Endangered Species Act (ESA). Hatchery produced summer-run steelhead and spring-run chinook are released in the river. Both are designed to be part of supplementation programs implemented under the auspices of the Lower Snake River Compensation Plan. The summer-run steelhead supplementation program is summarized here.

Program Goals, Constraints, and Design

The current supplementation/mitigation goal under the LSRCP is to return 2,000 adult summer-run steelhead to the to the compensation area annually. To achieve this return the program plans an annual release of 330,000 smolts. A goal for the numbers of natural -origin adults is not specified. The program goal includes restoring and maintaining the natural population and reestablishing sport and tribal fisheries. The program has operated under various broodstock management policies. In the early 1990's the program adopted Oregon's Wild Fish Management Policy under which no more than 25% of the natural adults could be removed from the escapement for use as hatchery broodstock, no more than 50% of the natural spawning population could be hatchery-origin, and no more than 70% of the broodstock could be composed of hatchery fish. Currently the program is not being managed with these criteria. According to a recent HGMP, egg takes are to include a 10% natural component, and three of every five natural-origin adult weir captures and three of nine hatchery-origin adult captures are retained for broodstock. All remaining natural- and four of nine hatchery-origin adults are to be released above the Little Sheep Creek weir. About 220 adults (1:1 sex ratio) are needed for broodstock each year. Performance standards for pre-spawning adult, egg-to-fry, fry-to-smolt, and smolt-to-adult survival are set at 90%, 90%, 90%, and 0.61%, respectively. Natural- and hatchery-origin adult returns, life history characteristics, productivity, life-stage survival of steelhead in hatchery culture, and natural juvenile production are to be monitored.

Adult summer-run steelhead are captured in a weir on Little Sheep Creek (Imnaha River RM 19) and then held and spawned at the Little Sheep Creek fish facility. Eggs are transferred to Wallowa Fish Hatchery for incubation to the eyed stage. Once eyed, the embryos are moved to Irrigon Fish Hatchery for final egg incubation, hatching, and juvenile rearing. At 10 to 13 months of age juveniles are transferred back to the Little Sheep Creek Facility and maintained for at least three weeks in acclimation ponds before release directly into Little Sheep Creek.

Hatchery Culture

Numbers of natural- and hatchery-origin summer-run steelhead adults trapped and held for broodstock are available from 1982 through 1998. Numbers for the last five years, and the mean for 1990 - 1998 are presented in Table A5.1. During initiation of the program - brood years 1982 through 1984 - only naturally produced adults were collected for broodstock. Since brood year 1987 the percentage of natural-origin adults included in the broodstock has varied from 19% to 3%, averaging 8%. Hatchery-origin adults predominate the broodstock and the program has not met the performance standard.

Table A5.1. Numbers of adult summer-run steelhead captured at the Little Sheep Creek Fish Facility trap, and their disposition 1994 - 1998.

Brood Year	Trap Capture			Passed Upstream			Hatchery Broodstock		
	N[1]	H	%N	N	H	%N	N	H	%N
1994	141	53	27.3%	41	36	53.2%	11	104	9.6%
1995	278	17	5.8%	12	34	26.1%	5	196	2.5%
1996	443	48	9.8%	41	68	37.6%	12	261	4.4%
1997	937	29	3.0%	24	53	31.2%	4	364	1.1%
1998	686	33	4.6%	25	116	17.7%	8	549	1.4%
Mean[2]			9.7%			31.7%			6.7%

1. N are natural-origin and H are hatchery-origin adults. 2. Mean over the 1990 - 1998 program.

Egg incubation and juvenile rearing at Wallowa and Irrigon fish hatcheries has met the program performance standards in most years - green egg to fry survival has averaged 90 % (79.2 - 98.3%) and fry-to-smolt survival has averaged 90.9% (83.9 - 93.8%). Since 1987 the smolt production goal has largely been met. Based on the analyzed brood years 1986 - 1992 smolt-to-adult survival rate has not achieved the 0.61% performance standard, averaging only 0.27%, and ranging from less than 0.01% to just over 0.60%. Consequently even though the smolt release targets are being achieved the supplementation program has failed to return the anticipated 2000 adult summer-run steelhead.

Integrated Natural-Artificial Production

Although the proportion of hatchery-origin adults in the population available to spawn naturally was variable, it was generally above 80%. This value indicates that adult recruits per spawner for naturally spawning (Rw) adults was below replacement, while adult recruits per spawner for hatchery spawning (Ra) was above replacement (Figure A5.1).

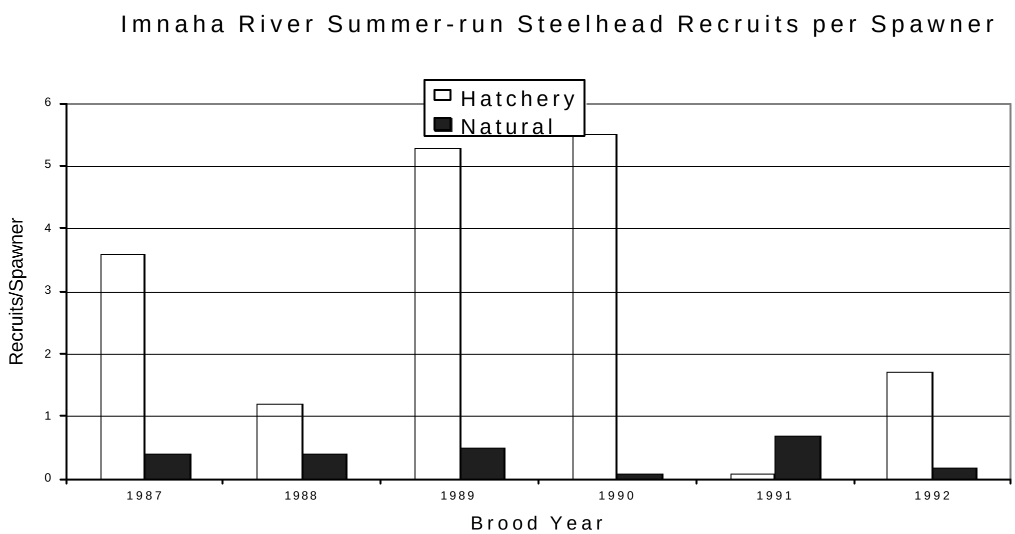

Figure A5.1. Adult summer-run steelhead recruits per spawner based on returns to the Little Sheep Creek weir.

The numbers of both hatchery-origin and natural-origin summer-run steelhead returns to Little Sheep Creek weir have not permitted managing the supplementation program and the naturally spawning population components within the program guidelines. The natural-origin summer-run steelhead population in the Imnaha River has not recovered following nearly two decades of supplementation (Figure A5.2).

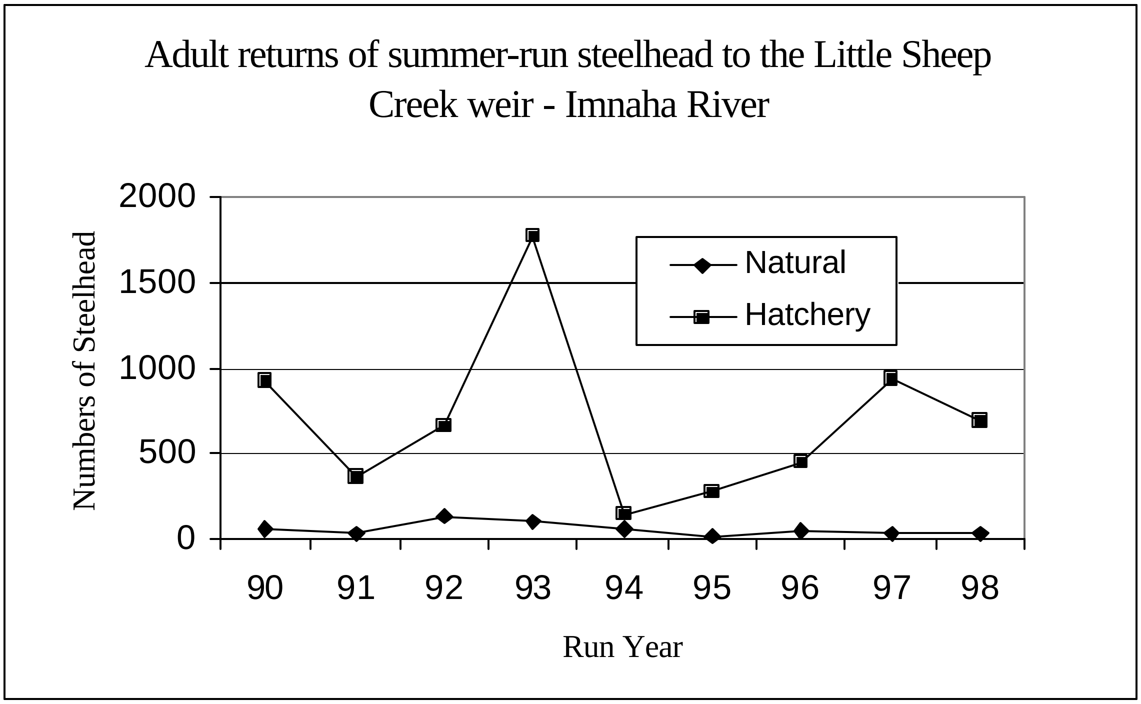

Figure A5.2. Adult summer-run steelhead abundance in the Imnaha River

Summary – Supplementing the Imnaha summer-run steelhead population since the early 1980s using the endemic population for broodstock, has not achieved LSRCP or US v Oregon program goals nor increased naturally produced steelhead abundance. The low SAR for hatchery-produced smolts has prevented the program from achieving the 2,000 adult return performance standard.

This summary was based on information reported in IHOT (1995), Whitesel et al. (1998), and Bryson (2001).

Blue Mountain Province

A 6. Imnaha Spring-run Chinook Salmon Supplementation Program

Background and History

The Imnaha River watershed drains approximately 980 square miles in northeastern Oregon, joining the Snake River at river mile (RM) 191.7, above Lower Granite Dam. The mainstem Imnaha extends approximately 63.5 miles upstream from the Snake River confluence to the North and South Forks in the Eagle Cap Wilderness. Primary tributaries, beginning at the confluence with the Snake River, include Cow Creek, Lightning Creek, Horse Creek, Big Sheep Creek, Freezeout Creek, Grouse Creek, Summit Creek, Crazyman Creek, Gumboot Creek, Dry Creek, Skookum Creek, South Fork, Middle Fork, and North Fork Imnaha River. Approximately 398 river miles of anadromous salmonid spawning and rearing habitat have been identified in the Imnaha subbasin. Spring- and fall-run chinook salmon (*Oncorhynchus tshawytscha*), and summer-run steelhead trout (*O. mykiss*) occur in the watershed. Native fall-run chinook salmon are nearly absent from the subbasin. Anecdotal accounts suggest that fall chinook may have historically used the lower 19.5 miles of the Imnaha mainstem for spawning, but likely did not occur above the town of Imnaha. The summer-run steelhead and spring-run chinook are listed as Threatened under the Endangered Species Act (ESA). Hatchery produced summer-run steelhead and spring-run chinook are released in the river. Both are designed to be part of supplementation programs implemented under the auspices of the Lower Snake River Compensation Plan. The spring-run chinook salmon supplementation program is summarized here.

Program Goals, Constraints, and Design

The current supplementation/mitigation goal under the LSRCP is to return 3.210 adult spring-run chinook salmon to the compensation area annually. To achieve this return the program plans an annual release of 490,000 smolts. A goal for the numbers of natural-origin adults is not specified. The program goal includes restoring and maintaining the natural population and reestablishing sport and tribal fisheries. The program was previously operated under Oregon's Wild Fish Management Policy under which no more than 25% of the natural adults could be removed from the escapement for broodstock, no more than 50% of the natural spawning population could be hatchery-origin, and no more than 70% of the broodstock could be composed of hatchery fish. Currently the program is managed under a Sliding Scale Management Framework. This framework is based on the assumption that at low escapement levels there is high demographic risk to the natural population. Therefore, at low escapement levels there are less risk containment measures placed on the hatchery program. At moderate to high natural escapement levels genetic risk containment measures in the form of criteria for proportion of the natural run that can be taken for broodstock and the proportion of natural spawners that can be hatchery origin fish are implemented. About 220 adults (1:1 sex ratio) are needed for broodstock each year. Performance standards for pre-spawning adult, egg-to-fry, fry-to-smolt, and smolt-to-adult survival are set at 90%, 90%, 90%, and 0.65%, respectively. Natural- and hatchery-origin adult returns, life history characteristics, productivity, life-stage survival of salmon in hatchery culture, and natural juvenile production are monitored.

Adult spring-run chinook salmon are captured using a picket weir at the Imnaha River Facility and transferred to Lookingglass Fish Hatchery where they are held and spawned. Egg incubation currently takes place at Irrigon and Oxbow hatcheries and juvenile rearing also takes place at Lookingglass Fish Hatchery. At 14 months of age juveniles are transferred back to the Imnaha River Facility and maintained for a month in acclimation ponds before release.

Hatchery Culture

Numbers of natural- and hatchery-origin spring-run chinook salmon adults trapped and held for broodstock are available from 1982 through 2000. Numbers for 1995 - 1999, and the mean for the duration of the program are presented in Table A6.1. During initiation of the program (brood years 1982 through 1984) only naturally produced adults were collected for broodstock. Since brood year 1990 however, the percentage of hatchery-origin adults included in the broodstock has varied from 29% to 86%, averaging 57%. In several brood years hatchery-origin adults predominated. Broodstock prespawn mortality and egg-to-smolt survival is variable and can be quite high. Smolt production goals have not been achieved in most years.

Table A6.1. Numbers of adult spring-run chinook salmon captured at the Imnaha Fish Facility weir, and their disposition 1994 - 1999.

Brood Year	Trap Capture			Passed Upstream			Hatchery Broodstock		
	N[1]	H	%N	N	H	%N	N	H	%N
1995	38	30	56%	0	0	------	36	25	59%
1996	145	99	59%	73	23	76%	55	22	71%
1997	84	398	17%	61	55	53%	15	104	13%
1998	150	233	39%	73	98	43%	59	92	39%
1999	73	323	18%	51	69	43%	21	231	8%
Mean[2]			43%			56%			43%

1. N are natural-origin and H are hatchery-origin adults. 2. Mean over the entire program.

Survival during egg incubation and juvenile rearing at Lookingglass Fish Hatchery has met the program performance standards in most years. Smolt-to-adult survival rate after release from the hatchery environment has not met the 0.65% performance standard in any year. Consequently the supplementation program has not generated the anticipated 3,210 adult spring-run chinook salmon return target for the Imnaha River.

Integrated Natural-Artificial Production

Adult recruits per spawner for naturally spawning individuals has been below 1.0 every year since 1983, and has been as low as 0.20. Adult recruits per spawner for hatchery spawning individuals has exceeded 1.0 for all broodyears except 1990, 1991, and 1992. The average for individuals being spawned and their progeny reared in the hatchery environment is near 4.0, while the average for individuals spawning naturally is under 0.50 (Figure A6.1).

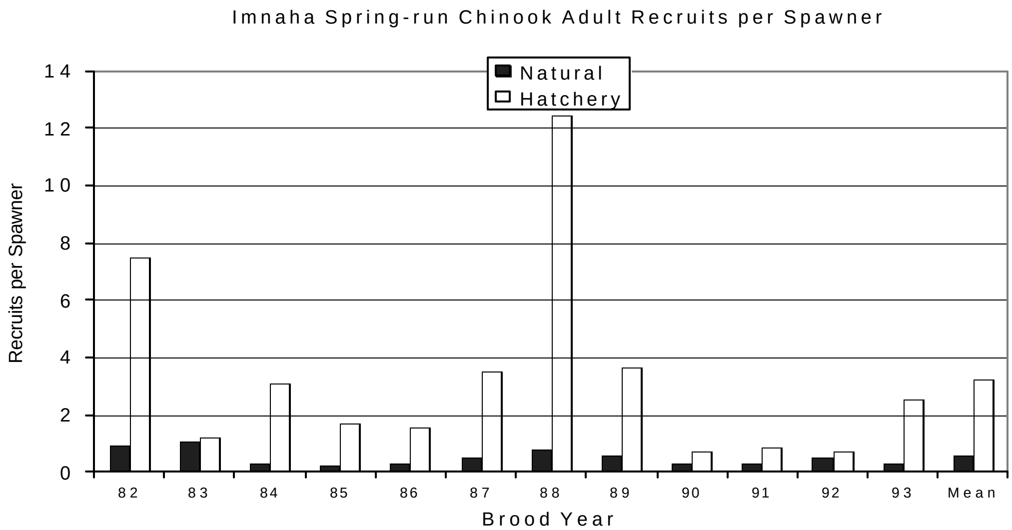

Figure A6.1. Adult recruits per spawner for naturally spawning and hatchery spawned Imnaha River spring-run chinook salmon.

There has been an appreciable return of hatchery-origin adults, and fishery co-managers believe these adults have reduced the rate of decline of natural-origin adults. Life history characteristics of hatchery and natural fish have been similar except for age at return with hatchery fish returning at an earlier age. Nevertheless, the supplementation of the Imnaha spring-run chinook salmon from 1984 through 2000 has not rebuilt the natural-origin component (Figure A6.2). In the 1999 return year there were many fewer natural-origin adults than in the years when the program was initiated (in the early 1980s).

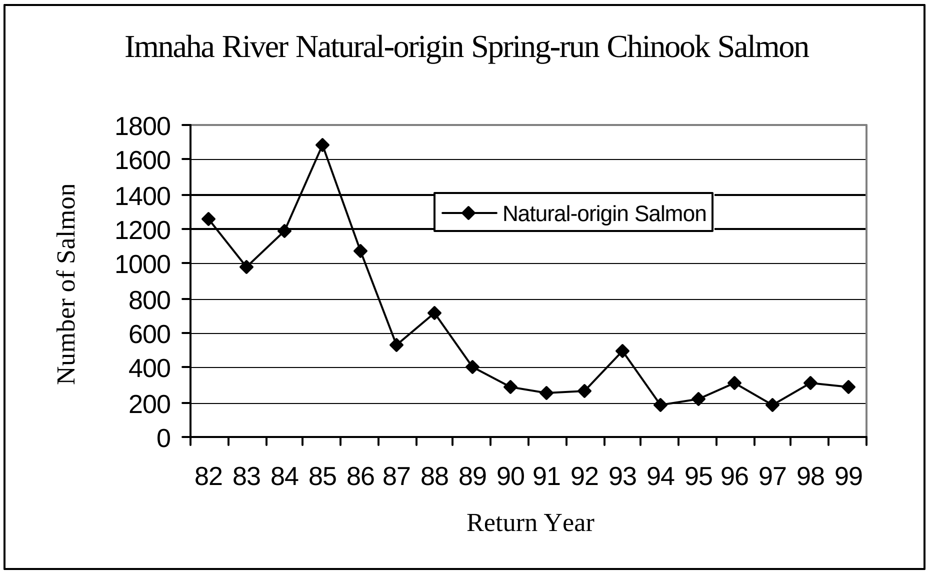

Figure A6.2. Estimates of the abundance of natural-origin spring-run chinook adults returning to the Imnaha River - 1982 through 1999.

This summary was based on information reported in IHOT (1995), Carmichael et al. (1998), and Bryson (2001).

Columbia Plateau Province

A 7. Tucannon spring-run Chinook Supplementation Program

Background and History

The Tucannon River watershed drains approximately 503-square miles in southeastern Washington State, joining the Snake River at river mile (RM) 62.2, between Little Goose and Lower Monumental dams. Pataha Creek is a major tributary. The mouth and lower two miles of the Tucannon River is marshland as a result of the reservoir formed by Lower Monumental Dam, 20 miles downstream on the Snake River. Spring- and fall-run chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and summer-run steelhead trout (*O. mykiss*) occur in the watershed. Native coho and fall-run chinook salmon are largely extirpated from the subbasin. There are naturally produced coho and fall-run chinook salmon that are believed to be the progeny of stray hatchery-origin adults. The summer-run steelhead and spring-run chinook are listed as Threatened under the Endangered Species Act (ESA). Hatchery produced summer-run steelhead and spring-run chinook are released in the river. Summer-run steelhead are produced under the Lower Snake River Compensation Program at Lyons Ferry Hatchery. This program has recently converted from using Lyons Ferry Hatchery steelhead to using broodstock collected in the Tucannon River. The spring-run chinook supplementation program is summarized here.

Program Goals, Constraints, and Design

The current supplementation/mitigation goal under the LSRCP is to return 1,152 adult spring-run chinook salmon to the Tucannon River annually. To achieve this return the program proposes a release of 130,000 yearling smolts annually. The program has goals of returning 1,152 hatchery-origin adults from the smolt release. Fifty natural- and fifty hatchery-origin adults are collected for broodstock each year. While ensuring proportional genetic contribution from both wild and hatchery salmon, 60% of the natural-origin adults are to be passed upstream for spawning. Constraints on the proportions of hatchery-origin and natural-origin adults available for natural spawning are not specified. Performance standards for pre-spawning adult, egg-to-fry, fry-to-smolt, and smolt-to-adult survival are set at 90%, 90%, 90%, and 2.5%, respectively (IHOT identifies a 2.5% smolt to adults survival, Gallinat et al. 2002 identifies a 0.87% survival). Natural- and hatchery-origin adult returns, life-stage survival of salmon in hatchery culture and natural juvenile production have been monitored since 1985.

Adult spring-run chinook salmon are captured at a trap located on-site at the Tucannon Hatchery (Tucannon River RM 98). Adults are transferred to Lyons Ferry Hatchery (Snake River RM 64 at its confluence with the Palouse River) and held for spawning, egg incubation, and early fry rearing. Once marked at Lyons Ferry Hatchery, juveniles are transferred back to the Tucannon Hatchery to be reared through winter. In mid-February, the spring-run chinook are transferred upstream to the Curl Lake Acclimation Pond (Tucannon RM 103) for a minimum of three weeks before volitional release in late April.

Hatchery Culture

Numbers of natural- and hatchery-origin spring-run chinook adults trapped, held for broodstock, and passed upstream, as well as prespawning mortalities are available from 1986 through 2001. Numbers for the last five years, and the mean for the duration of the program are presented in Table A7.1. During initiation of the program (brood years 1985 through 1988) only naturally produced adults were collected for broodstock. Since 1989 the proportion of hatchery-origin adults included in the broodstock has varied from 46% to 97%, averaging 62%. Although the mean is only marginally higher than the program design, in several brood years hatchery-origin adults predominated. Broodstock mortality was quite high in the program's early years, but apparently associated problems have been solved.

Table A7.1. Numbers of adult spring chinook captured at the Tucannon Fish Hatchery trap, and their disposition 1986 - 2001.

Year	Trap Capture		Broodstock Collected			Passed Upstream			Pre-spawning Mortality	
	N[1]	H	N	H	% H	N	H	%H	N	H
1997	99	160	43	54	56%	53	106	65%	4	4
1998	50	43	48	41	46%	1	1	50%	3	0
1999	4	136	4	132	97%	0	0	0%	0	5
2000	25	180	12	69	85%	13	94	88%	0	3
2001	405	276	52	54	51%	353	222	39%	0	0
Mean[2]	156	126	52	52	62%	96	72	54%	8	12

1. N are natural-origin and H are hatchery-origin adults. 2. Mean over the entire program. Years used for trap capture, broodstock collected, numbers passed upstream, and pre-spawning mortality varies.

Egg incubation and juvenile rearing at Lyons Ferry and Tucannon fish hatcheries has met the program performance standards in most years (Table A7.2). Smolt-to-adult survival rate has not met the performance standard in any year (regardless of whether the standard is 0.87 or 2.5%). Consequently the supplementation program has not returned the proposed target of 1,152 adult spring-run chinook salmon.

Table A7.2. Summary of the performance of hatchery rearing spring-run chinook salmon in the Tucannon River subbasin 1985 - 2000.

Brood Year	Eggs Incubated	Smolts Released	Egg to Smolt Survival	Hatchery-Origin Recruits	Smolt-to-Adult Survival	Egg-to-Adult Survival
1994	161,707	130,069	0.80	34	0.03%	0.02%
1995	85,772	62,272	0.73	180	0.29%	0.21%
1996	117,287	76,219	0.65	260	0.34%	0.22%
1997	144,237	24,186	0.17	181	0.75%	0.13%
1998	161,019	127,939	0.79	103	0.08%	0.06%

Mean	135,539	98118	0.73	168	0.22%	0.13%

Integrated Natural-Artificial Production

Life-stage survival for naturally produced salmon is derived from population estimates of spawning adult females, their fecundity, and population estimates of juveniles and smolts from stream surveys and outmigrant trapping (Table A7.3). As anticipated, egg-to-smolt survival for natural spawning adults is much less than for hatchery spawned adults. Hatchery rearing provides is a 15.7 fold survival increase during juvenile rearing. Smolt-to-adult survival is five-fold greater for naturally produced smolts than for hatchery produced smolts. Overall this provides approximately a three-fold benefit to adult production through hatchery rearing (Table A7.4). The percentage of hatchery-origin adults in the salmon passed upstream to potentially spawn was variable, ranging from 0% to 88%.

Table A7.3. Estimates of the numbers of incubated eggs, smolts produced, and returning adults from natural spawning of spring-run chinook in the Tucannon River, and life-stage survivals.

Brood Year	Spawning Females	Eggs Incubated	Smolts Produced	Egg to Smolt Survival	Natural-Origin Recruits	Smolt-to-Adult Survival	Egg-to-Adult Survival
1993	265	930,189	49,600	5.3%	204	0.41%	0.02%
1994	43	175,676	6,900	3.9%	12	0.17%	0.01%
1995	7	36,568	75	0.2%	6	8.00%	0.02%
1996	75	254,278	1,612	0.6%	66	4.09%	0.03%
1997	74	257,070	21,057	8.2%	717	3.41%	0.28%
1998	29	111,727	5,508	4.9%	9	0.16%	0.01%
Mean[1]	181	665,787	28,027	4.2%	222	1.63%	0.05%

1. Mean of 1985 through 1998 broods

Even with the increased numbers of returning adults available to spawn as a consequence of the hatchery rearing the natural adult abundance decreased steadily from the mid 1980's through 2000. Like many other locations around the Columbia River Basin, numbers of natural-origin adults increased in 2001 (Figure A7.1). The number of adult recruits per hatchery spawner did not exhibit an increase comparable to the 1997 year-class natural spawning component. The abundance of returning adults was so low that in 1994, 1995, 1998, and 1999 no adults were passed above the Tucannon Fish Hatchery trap for natural spawning. During those years redd counts below the trap indicated that some natural spawning took place. Adult recruits per spawner for naturally spawning (Rw) adults was below replacement, while adult recruits per spawner for hatchery spawning (Ra) was above replacement (Table A7.4).

Table A7.4. Estimated recruits per spawner (adult progeny per parent) for naturally spawning (Rw) and hatchery spawning (Ra) Tucannon spring-run chinook.

	Natural Spring-run Chinook			Hatchery Spring-run Chinook			
Brood Year	No. of Spawners	No. of Recruits	Recruits/ Spawner	No. of Spawners	No. of Recruits	Recruits/ Spawner	H:N Advantage
1993	436	204	0.47	91	207	2.27	4.8
1994	70	12	0.17	69	34	0.49	2.9
1995	11	6	0.55	39	180	4.62	8.4
1996	138	69	0.50	74	260	3.51	7.0
1997	146	717	4.91	89	180	2.03	0.4
Mean 1985 - 1997			0.86			2.52	2.9

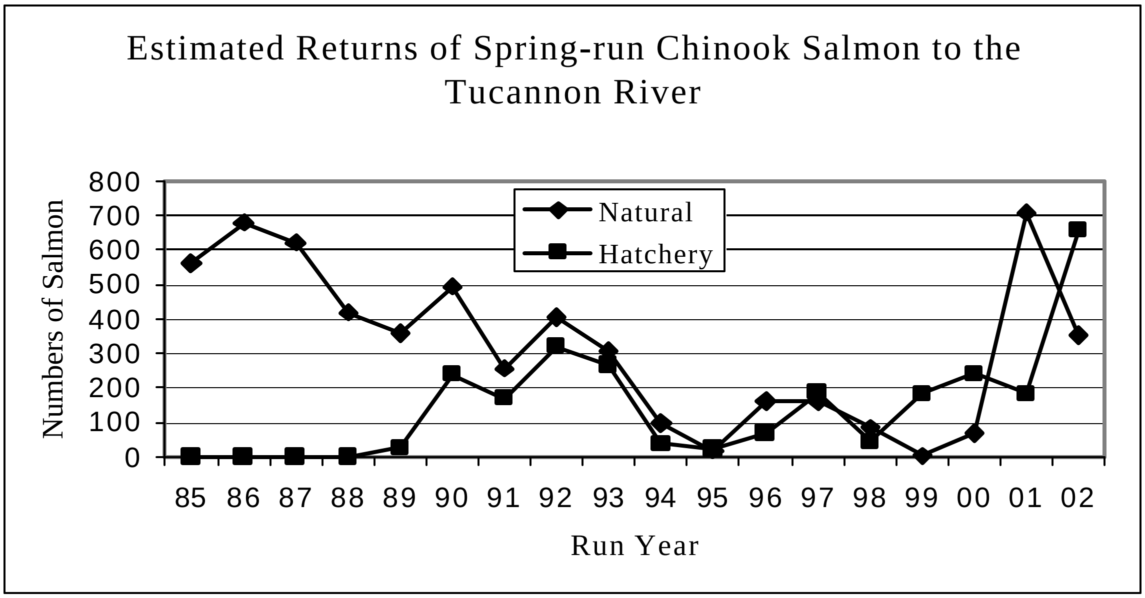

Figure A7.1. Adult spring-run chinook salmon abundance in the Tucannon River

Summary – Supplementation of the Tucannon River spring chinook population since the mid-1980s using the endemic population for broodstock has not resulted in increased overall or naturally produced chinook abundance. Furthermore, because of the dramatic decline of adult returns in the mid-1990s, a captive broodstock program was added to prevent their extinction from the basin. The low SAR for hatchery-produced smolts has prevented the program from achieving the 1,150 adult return performance standard, even in one year class (1997) experiencing improved ocean conditions.

This summary was based on information reported in IHOT (1995), Gephart and Nordheim (2001) and Gallinat et al. (2002).

Columbia Plateau Province

A 8. Yakima River Spring-run Chinook Supplementation

Background and History

The Yakima River is located in south central Washington State and drains an area of 6,155 square miles. The basin contains about 1,900 miles of perennial streams, originating in the Cascade Range above Keechelus Lake and flows 214 miles southeastward to its confluence with the Columbia River (RM 335.2) near the tri-cities. The basin consists of the lower Yakima River (mainstem below the city of Yakima) and two major up-stream tributaries, the Upper Yakima and Naches River. The basin, however, is one of the most intensively irrigated areas in the United States (oregon.usgs.gov/projs_dir/yakima). Major land use activities include growing and harvesting timber, grazing on non-irrigated land, intensive agriculture on irrigated land, and urbanization. The Bureau of Reclamation's Yakima Project involves seven irrigation divisions and provides water to irrigate almost one-half million acres. The Project involves six storage reservoirs, 416 miles of canals, and eight low-head diversion dams. These latter dams include three important sites for spring chinook enumerations: the Prosser dam (RM 47.1 Yakiman mainstem) and Chandler downstream facility, Roza dam (RM 127.0 upper Yakima, upstream and downstream facilities), and the Cowiche dam (RM 17.1) on the Naches River. Irrigation involves a significant proportion of the annual water flow for the Yakima and effects seasonally water quality parameters for the basin.

The Yakima Subbasin Summary submitted for the Provincial review identifies 48 species of anadromous, resident, and exotic fishes. The basin currently supports natural production of spring and fall chinook, coho salmon, and summer steelhead (steelhead are currently listed as "threatened" under the ESA). Endemic stocks of coho and summer chinook salmons are also considered extirpated. Sockeye salmon were noted as historically abundant but were also extirpated following completion of impassable storage dams below all the natural lakes. Spring chinook, however, continue to utilize most of the spawning areas used historically (with the exception of the lower Yakima tributaries) but the major difference is that their abundance is reduced. Estimates of the size of historical Yakima spring chinook returns range from ~50,000 (Kreeger and McNeil 1993) to 200,000 (Anon. 2000)[2]. Returns have been greatly reduced from these levels since the early 1900s (due to causes within and outside of the basin). Figure A8.1 presents the counts of adults and jack spring chinook at Roza Dam since 1940 and indicates the depressed returns over this period (this figure was used in the Yakima Subbasin Summary but the basis for some of the historical data is uncertain according to the YKFP). Fisheries on spring chinook in the lower Columbia River continued into the 1970's but commercial fishing has not occurred since 1977. The graph is stopped at the 1998, before returns from the Yakima Fisheries supplementation program began.

[2] The Kreeger and McNeil (1993) and Anon (1990) references cited in www.nwcouncil.org/library/recommend/yakimatrp2.doc.

Hatchery-reared spring chinook juveniles have been released into the Yakima basin since at least 1959 (Yakima Subbasin Summary). Most of these releases were made during the 1980's (see Table 32 Yakima Subbasin Summary) as part of a research program and little adult production is believed to have resulted from those efforts. These releases consisted largely of Carson chinook stock and occurred primarily into the upper Yakima River. Adult returns of Carson stock releases were trapped and removed at Roza Dam from 1986-1990.

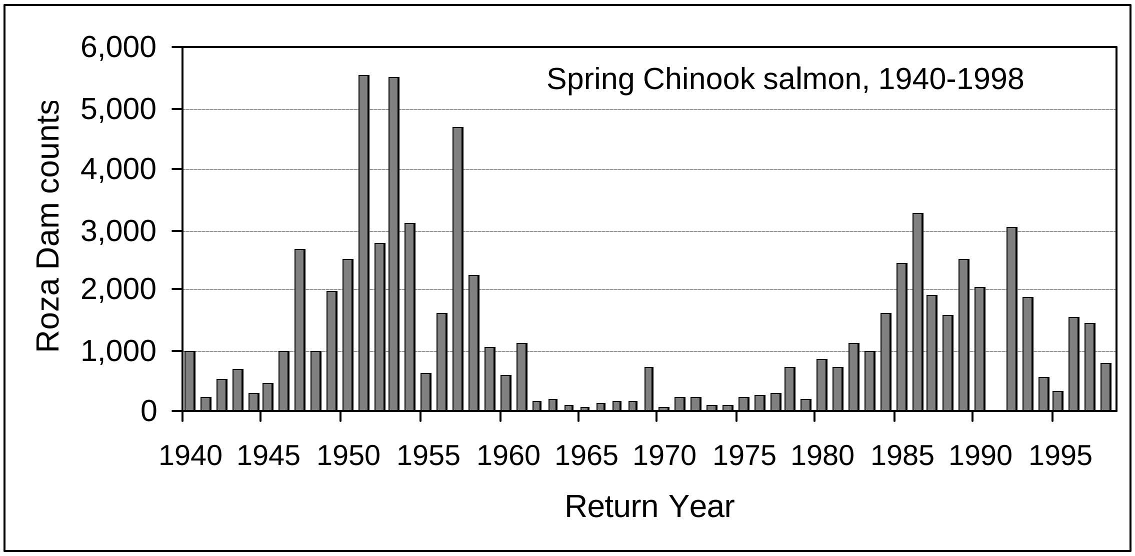

Figure A8.1. Historical returns of spring chinook (adults and jacks) counted at Roza Dam, upper Yakima River, 1940-1998.

However, to increase the natural production of spring chinook in the upper Yakima River and to restore fishing in the Yakima basin, the Yakima/Klickitat Fisheries Project began artificial production of Yakima spring chinook in 1997 at the Cle Elem Supplementation and Research Facility. Initiation of this program followed a long period of project design and consultations.

Since 1982, the Yakima River basin has been a priority area of emphasis for the Northwest Power Planning Council including the construction of a hatchery to "enhance the fishery for the Yakima Indian Nation as well as other harvesters" (NPPC 1982); and in 1984, supplementation was added to the fish production objectives. As early as 1987, the Council emphasized that the purpose of the project was to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining genetic resources. It also emphasized that evaluation of supplementation and use of adaptive management methods in this program could provide critical information about the potential for supplementation to increase salmon and steelhead runs in other areas of the Columbia River basin. Supplementation was defined as the use of hatchery fish to initiate and/or augment natural production, i.e., to contribute to natural spawning escapement and subsequent recruitment.

Program Goals, Constraints, and Design

The Yakima Fishery Project's Final Environmental Impact Statement (YKP, 1996) is the primary guiding document for the project and its related monitoring and evaluation programs (the latter are described in the document "Yakima Fisheries Project Spring Chinook Supplementation Monitoring Plan" (DOE/BP 64878-1, April 1998). Section 1.2 of the final EIS states the need and purposes for this program:

> *Conventional fish hatcheries traditionally have produced large numbers of artificially propagated fish to increase harvest opportunities and, in some cases, to bolster natural production. However, important questions regarding hatchery production have arisen in three areas:*
>
> 1. *The survival of hatchery fish after release from the hatchery,*
> 2. *The impacts of hatchery fish as they compete with wild populations, and*
> 3. *The effects of hatchery propagation on the long-term genetic fitness of fish stocks.*
>
> *The YFP is being designed (1) to provide resource managers with knowledge regarding these issues and (2) to identify and apply improved methods for carrying out hatchery production and supplementation of natural production.*
>
> *Supplementation aims to rebuild natural anadromous fish spawning runs by raising and releasing artificially propagated fish into natural streams and by increasing natural production of both naturally and artificially produced fish. Its goals are to increase the numbers of naturally spawning fish, while maintaining the long-term genetic fitness of the fish population being supplemented and keeping adverse genetic and ecological interactions with non-target species or stocks within acceptable limits.*

The goals and objectives for the project were then described under four topics: Genetic, Natural Production, Experimentation, and Harvest.

The stated objectives are:

Genetic Objective 1: Manage genetic risks (extinction, loss of within- and between-population variability, and domestication selection) to all stocks from management of the fishery. (5 strategies described)
Genetic Objective 2: Conserve upper Yakima and Naches stocks of spring chinook salmon. (identify and minimize artificial mixing of 3 genetic stocks of spring chinook in the Yakima basin)
Genetic Objective 3: Conserve the American River stocks of spring chinook salmon.

Natural Production Objective 1: Optimize natural production of spring chinook with respect to abundance and distribution. (3 strategies described)

Natural Production Objective 2: Optimize natural production of spring chinook salmon while managing adverse impacts from interactions between and within species and stocks.
Natural Production Objective 3: Maintain upper Yakima spring chinook natural production at a level that would contribute an annual average of 3,000 fish to the Yakima Basin adult return.
Natural Production Objective 4: Maintain natural escapement of upper Yakima spring chinook (hatchery and wild) at an average of 2,000 adult returns and consistently greater than 1,700 spawners per year.

Experimentation Objective 1: Learn to use supplementation as defined by the RASP (RASP 1992) to increase natural production of upper Yakima spring chinook and increase harvest opportunities.

Six strategies or programs were described to meet this objective including construction of an artificial spawning channel at Cle Elum, comparison of two hatchery treatments within Cle Elum (optimal conventional treatment versus semi-natural treatments, OCT vs. SNT), extensive monitoring of returning adults collected at Roza Dam, multiple and marked OCT and SNT (replicates by pond) groups (18 groups at 45,000 fish per group) released from three acclimation sites in the upper Yakima basin, and conduct experiments to detect a 50% or greater difference (with 90% certainty) between test treatments for response variables.

Harvest Objective 1: Increase harvest opportunities for all fishers consistent with requirements of genetic, natural production, and experimentation objectives. (The strategy stated for this objective involves selective and/or "status-index harvest" policies to increase opportunity for all fisheries in the Yakima basin).

Project Overview: Basically, the design of the Yakima Fishery Project involves the establishment of a new endemic broodstock developed from upper Yakima spring chinook and the development of Cle Elum Supplementation and Research Facility (CESRF). Within Cle Elum, juveniles may be reared under "optimal conventional" (OCT) hatchery conditions or under conditions intended to simulate semi-natural rearing (SNT, painted backgrounds, floating cover, sub-surface feeding, etc.). The latter is intended to condition the juveniles to more natural-like responses to stimuli and improve survival rates after release. All fish to be released will be fin-clipped (adipose fin removed for identification of a hatchery fish) and one third of the OCT and the SNT treatments will each be distributed to one of three acclimation sites for release. Upon return, all spring chinook returning to the Yakima will be enumerated at Prosser Dam and all upper Yakima spring chinook again enumerated at Roza Dam. The difference between the Prosser counts, estimated harvest, and the Roza counts represents the spawning escapement to the Naches and American stocks (these latter fish may be sampled at the Cowiche Dam but sampling at that location is still being developed). At Roza Dam, broodstock for Cle Elum are collected but must be non-clipped fish to ensure that parents are at least one generation removed from hatchery rearing. Facilities at Roza Dam provide for extensive sampling and tag interrogation. Following review by the

ISRP, a conventional hatchery broodstock will also be maintained at Cle Elum so that the genetic guidelines developed for YFP can be compared against more typical or traditional hatchery program utilizing a closed broodstock. This broodstock line will be maintained independently of the Supplementation program. A very extensive monitoring and evaluation program has been developed by the Yakima Fishery Project and documented in BPA project #199506325.

Success of the supplementation program will be assessed by comparison with a line of standard hatchery fish (initiated in 2002 and to remain a closed broodstock) managed within the Cle Elum facility, and compared against production dynamics in the Naches/American river stocks. These latter populations will act as the natural "references" on the supplemented production in the Upper Yakima (both the naturally spawning components and the hatchery produced fish). The initiation of a new "hatchery" broodstock within Cle Elum is a unique opportunity to compare supplementation programs with the traditional style of hatchery production and has been deliberately developed to study changes in such broodstocks. The natural references using the Naches populations is a significant development incorporated by the YKFP following extensive dialogue with their advisory committees and the ISRP. In total, this program likely represents the most comprehensive research and monitoring program addressing supplementation as a production management tool.

1999 and 2000 Conversion Period

The first returns of production from the Cle Elum hatchery were Age-3 (called Jacks) chinook that returned in 2000. However, the estimated number of Age-3 hatchery chinook returning in 2000 was only 688 Jacks in a total return of 12,327 chinook to Roza Dam. The 2000 return was obviously much larger than any return recorded since 1940 as presented in Figure A8.1. This return in 2000 was attributed to a very strong survival of the 1996 brood year for naturally spawning spring chinook in the Yakima basin (improved returns were also noted in the Naches and American river stocks). Recent year returns to Roza Dam (counts of spring chinook) are summarized in Figure A8.2

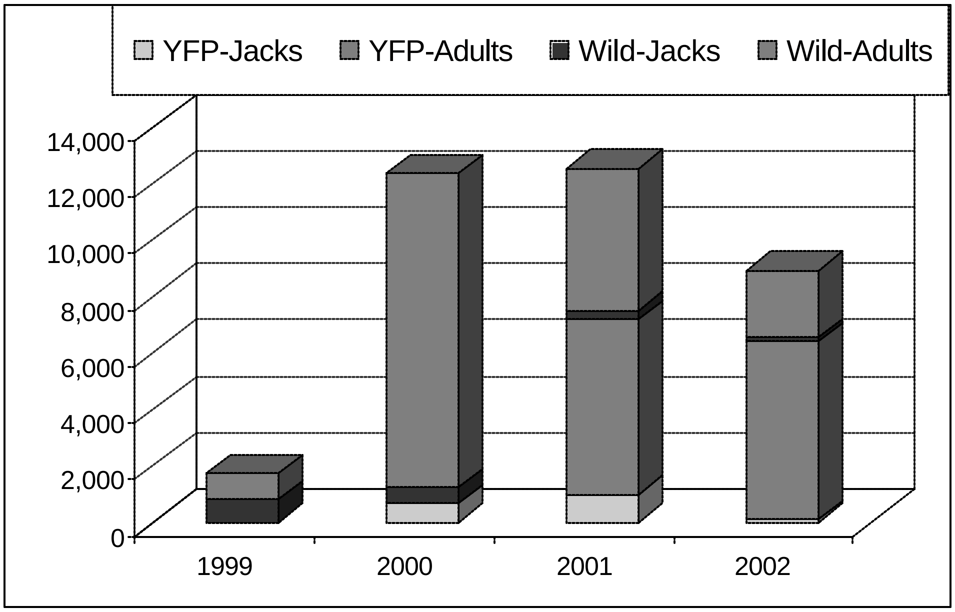

Figure A8.2. Total return of upper Yakima spring chinook at Roza Dam, 1999 to 2002. Returns are identified by naturally spawning (Wild-Jacks and Wild-Adults) chinook and Cle Elum supplementation program (YFP-Jacks and YFP-Adults) chinook. YFP-Jacks for 2002 do not show on the scale, actual value was 86 Jacks, and Wild-Jacks was 133.

Data in the Yakima Subbasin Summary demonstrates that the average smolt-to-adult survival rate for Yakima spring chinook between the 1981 and 1995 spawning years was 2.2% (standard deviation 1.03%). The estimated survival for the 1996 spawning year, however, improved to 8.4% and indicates that survival during downstream passage and/or the marine environment accounted for this return of naturally produced fish.

Hatchery Culture

The culture history for upper Yakima spring chinook at Cle Elum began in 1997 with the collection of endemic broodstock at Roza Dam. Broodstock collected and smolts produced during the initial years of production at Cle Elum are presented in Table A8.1 (recent data provided by B. Bosch, Yakima Fisheries Program).

Table A8.1. Initial brood years for the Cle Elum Supplementation and Research Facility.

Data Category:		**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Wild/Natural	Male	114	181	149	198	217	212
Brood collected	Jacks	0	0	339	41	30	37
	Female	147	227	250	326	348	380
% of total wild/natural return transferred		18.1%	51.3%	43.3%	4.9%	11.1%	24.8%
Spawned Fish[1]	Male	105	143	90	152	135	128
	Jacks	0	0	125	19	18	26
	Female	133	199	222	279	225	264
eggs per female[2]		3,739	3,760	3,850	3,750	3,818	3,792
total egg take[2]		482,300	725,700	832,400	937,500	408,600	883,600
Est. Smolts released[3]		386,048	589,683	758,789	838,174	371,284	Not avail
% Egg-to-Smolt Survival Rate		80.0%	81.3%	91.2%	89.4%	90.9%	Not avail
Est. % BKD Loss[4]		2.6%	1.4%	2.7%	9.2%	48.6%	10.0%

Footnotes: **1**. Spawned Fish are only those fish used for production releases (fish for spawning channels not included). **2**. data for low-moderate BKD (ELISA rank < 6) production females.
3. Number of tagged smolts less documented mortality from tagging to volitional release dates.
4. The estimated BKD loss for the 2001 brood year was based on the loss of eggs from the 225 females spawned to the total effective egg take as defined in footnote 2.

Comparisons of Returns since the 1997 Brood Year

<u>Returns Per Spawner by sub-stock</u>: (based on jack and adult returns to the mouth of the Yakima River for spring chinook through 2002). In the following tables, 'Estimated Spawners' are the number of wild fish collected at Roza Dam and taken to CESRF as broodstock for the production lines for supplementation releases.

Table A8.2. Brood table and returns through 2002 for Cle Elum Supplementation program.

Brood	Estimated	Estimated Returns to Yak. R. Mouth				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1997	261	741	7,753	176	8,670	33.22
1998	408	1,242	7,939		9,181	22.50
1999	738[a]	134				
2000	567					
2001	595					
2002	629					

Footnote [a]: 339 of these spawners were Age-3 Jack males.

Table A8.3. Brood table and returns through 2002 for Upper Yakima natural production.

Brood	Estimated	Estimated Returns to Yak. R. Mouth				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1997	1,204	620	5,797	150	6,567	5.45
1998	390	434	2,807		3,241	8.32
1999	1,021[a]	164				
2000	11,864					
2001	12,084					
2002	8,073					

Footnote [a]: approximately 46% of these fish were Age-3 Jack males.

Table A8.4. Brood table and returns through 2002 for Naches/American River natural production (reference populations for comparison with Upper Yakima and Cle Elum). These populations also have Age-6 returns that can be up-dated after 2003.

Brood	Estimated	Estimated Returns to Yak. R. Mouth				Returns/
Year	Spawners	Age-3	Age-4	Age-5	Total	Spawner
1997	953	226	5,408	1,377	7,011	7.36
1998	917	363	2,167		2,530	2.76
1999	418[a]	185				
2000	4,260					
2001	5,823					
2002	3,041					

Footnote [a]: approximately 46% of these fish were Age-3 Jack males. However, this value is based on sampling in the Upper Yakima and may not be representative of these populations.

Smolt to Adult Survivals: based on smolts out-migrating past Chandler Dam for both wild smolts (Naches and Upper Yakima combined since they are not identified by stock) and supplementation smolts identified to OCT and SNT treatments in Cle Elum facility.

Table A8.5. Smolt-to-Adult survival estimate for Cle Elum Supplementation production. Adult production values from tables above and account for adults returning to the mouth of the Yakima River.

Brood	Migratory	Number of Smolt Outmigrants			% SAR	% SAR
Year	Year	OCT	SNT	Total	With Jacks	w/o Jacks
1997	1999	45,469	56,042	101,511	8.5%	7.8%
1998	2000	109,087	116,020	225,107	4.1%	3.5%
1999	2001	235,316	216,433	451,749		
2000	2002	193,515	132,228	325,743		

Table A8.6. Smolt-to-Adult survival estimate for combined natural production (Naches and Upper Yakima rivers). Adult production values from tables above and account for adults returning to the mouth of the Yakima River.

Brood	Migratory	Number of Smolt Outmigrants	% SAR	% SAR
Year	Year	(combined for total wild)	w/ Jacks	w/o Jacks
1997	1999	258,751[a]	5.3%	4.9%
1998	2000	61,531	9.4%	8.1%
1999	2001	96,734		
2000	2002	367,013		

Footnote [a]: The smolt estimate for 1999 migration includes a portion of the smolts migrating past Chandler Dam in the winter. The basis of this calculation could not be described by YFP but this value is the YFP's total smolt value. If the winter smolts are not included as in the subsequent years, then the 1997 brood %SAR values increase to 6.4% (with Jacks) and 6.0% (without Jacks).

Based on these initial returns, the SAR for spring chinook produced in the Cle Elum Hatchery had a better survival rate than the natural population estimated in the 1997 brood year but the situation was reversed in the 1998 brood year.

The survival of OCT and SNT fish from Cle Elum can also be compared but this analysis requires extensive de-coding of coded-wire tags. Consequently, the results through the 2001 returns are available on the YFP website but no brood year return is complete yet (for example, the 1997 brood requires results decoded through the 2002 return year). The initial returns for the 1997 brood through 2001, based on the coded-wire tag data indicate a higher survival rate for the OCT fish than the SNT treatment[3]. However, a recent analysis by Neeley (2002) based solely on the PIT tag data indicates that there is no

[3] ykfp.org/docs/Adult%20Survival/1997Brood/RecapSum.xls

significant difference in survival rates of OCT and SNT treatments and that similar results are reported for the 1998 brood year.

Harvest Rates In-river:
One objective for the YFP was to also increase in-river harvest opportunities for Native and non-Native users. Since the improved returns in 2000, harvest in-river has been increased but harvest rates have been maintained at a modest level (Table A8.7).

Table A8.7. Numbers of salmon harvested in the Yakima River, and estimated in river harvest rates.

Return	Tribal		Non-Tribal		River Totals			In-River
Year	Adults	Jacks	Adults	Jacks	Adults	Jacks	Total	Harvest Rate
2000	2,271	87	92	8	2,363	95	2,458	12.8%
2001	2,510	96	1,908	116	4,418	212	4,630	19.9%
2002	2,507	73	523[a]	5	3,030	78	3,108	20.6%

Footnote [a]: The estimated harvest includes an allowance for catch-and-release mortality. A 10% mortality rate was assigned to the release of 357 fish in a non-retention fishery.

In-river harvest since 1982 had been limited to Tribal fisheries with an average harvest rate of 12.1% (Bosch 2002).

At this time, there is no information available concerning harvest of Yakima spring chinook in the Columbia River or ocean fisheries. Based on available coded-wire tag data though harvest managers have long assumed that Columbia River spring chinook are not harvested in any abundance in marine fisheries. Recent analysis by YFP staff indicated that only 3% of CWT recoveries for the 1997 and 1998 brood years were reported from ocean fisheries.

Distribution of Redds:
Successful supplementation should lead to sustained increased production from natural spawners. One immediate indicator of increased spawning activity is the annual count of spawning nests or redds.

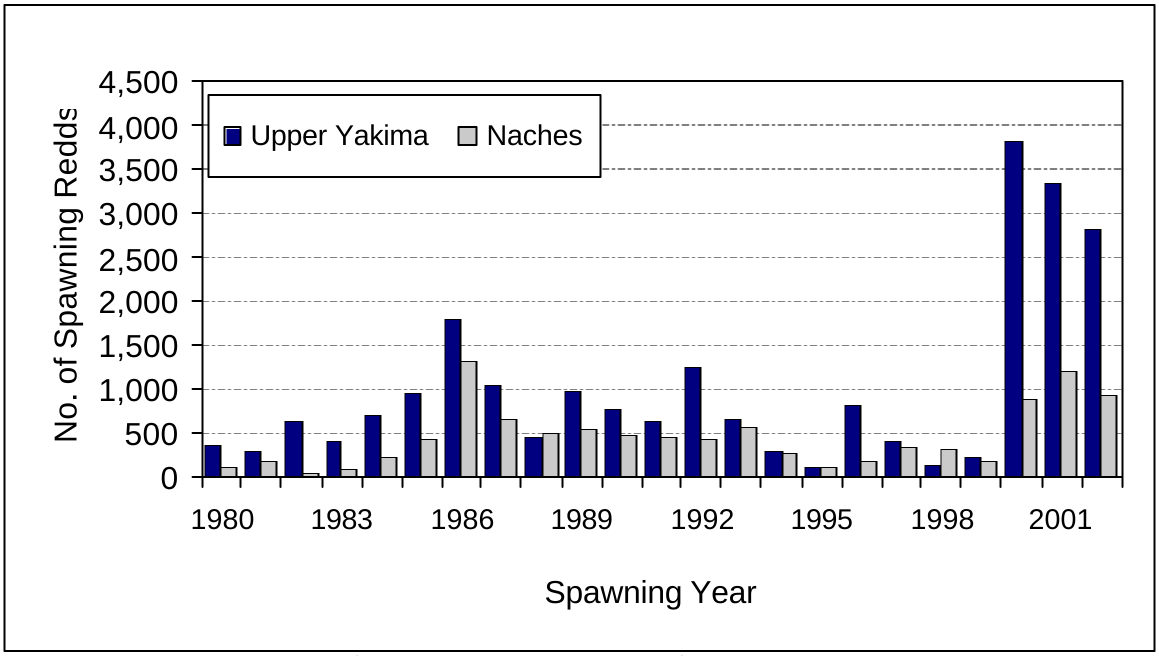

Figure A8.3. Distribution of spawning nests (redds) of spring chinook salmon in the Naches tributary (6 spawning areas included) and Upper Yakima River, including areas downstream of Roza Dam (in some years water conditions preclude accurate counts and estimates are based on historical proportions for this reach.

Increased redd counts have occurred in both major tributary areas but the increase is notably larger in the Upper Yakima at this time.

Run Timing of Supplemented and Wild sub-stocks:
The extensive tagging and monitoring program established by the YFP provides an opportunity to examine many aspects of the supplemented (hatchery-reared) and naturally produced spring chinook. For example, tagging provides for monitoring age-at-maturity rates, growth rates, survival rates (above) and run timing. In the first two years of data, it is interesting that the naturally produced fish had slightly earlier run-timings than the supplemented fish in both years (Figures A8.4 and A8.5).

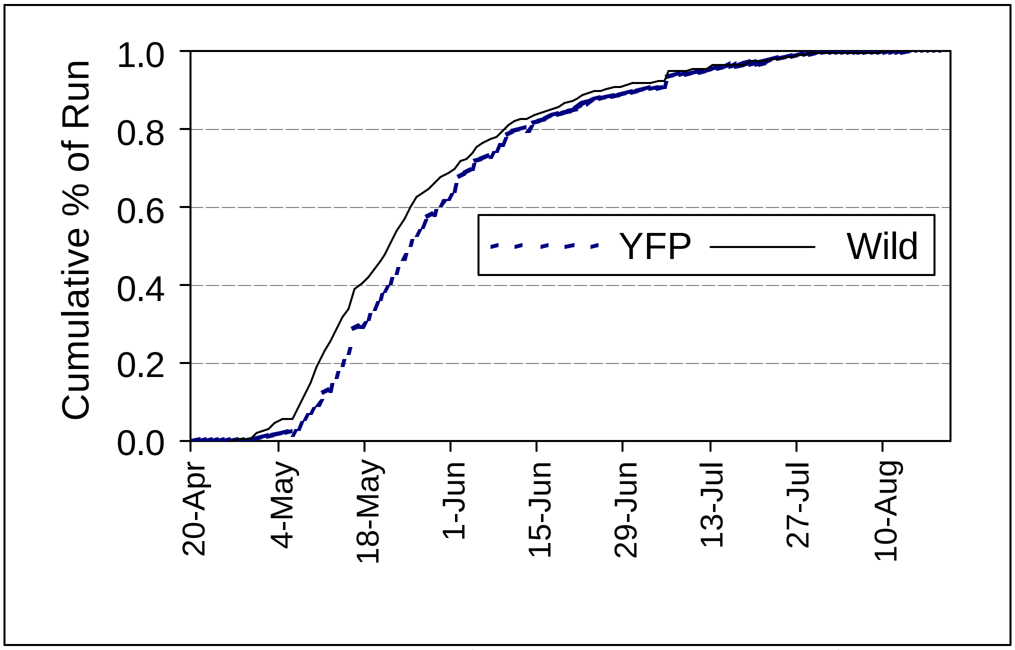

Figure A8.5 . Cumulative proportion of the total run past Roza Dam for the YFP (supplemented chinook) and naturally produced chinook (Wild) in 2001. The date for 50% passage of the Wild fish was May 22 and for the YFP fish was May 25.

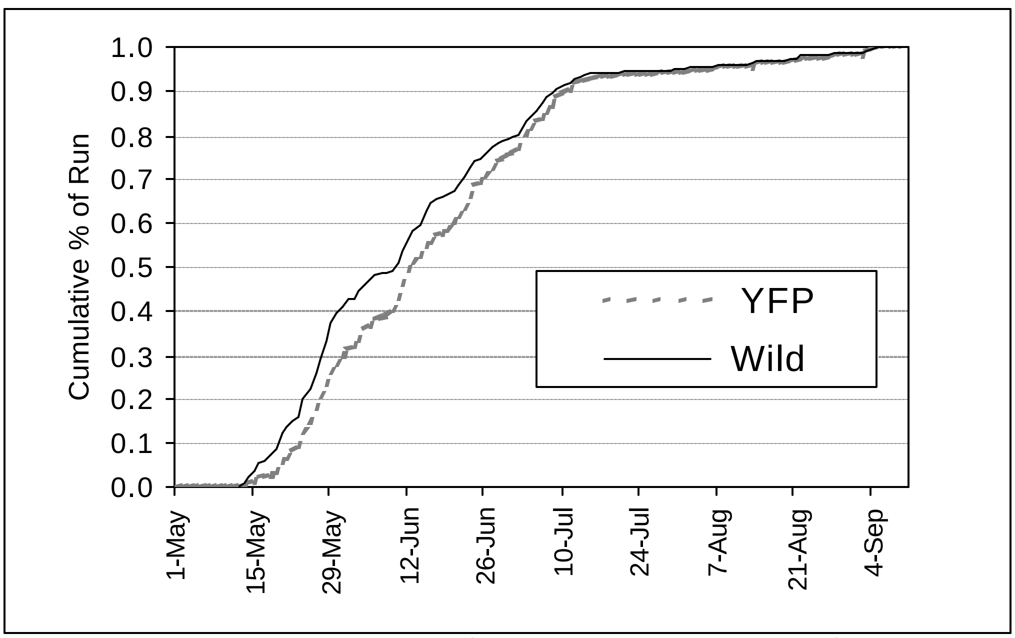

Figure A8.6. Cumulative proportion of the total run past Roza Dam for the YFP (supplemented chinook) and naturally produced chinook (Wild) in 2002. The date for 50% passage of the Wild fish was June 9 and for the YFP fish was June 13.

Summary – Assessment of the Yakima Fisheries Program of supplementation for Upper Yakima spring chinook is in its very early phase. Only the initial brood year (1997) of the new endemic stock program has completed returns through 2002. However, after years of planning, this program could be one of the most informative research programs in the Columbia Basin.

Production of smolts in the Cle Elum hatchery achieved its goal by the 1999 brood but has had one year of disease problems that limited production of the 2001 brood. Based on the completed analysis of Neeley (2002), and only one the 1997 brood returns, survival rates for OCT and SNT rearing treatments were equivalent. Estimated recruits-per-spawner for the 1997 and 1998 brood years has shown that the supplemental production can have significantly higher production rates (approximately 3-6 times the Upper Yakima stock) but comparisons of the smolt-to-adult survival rates are much more comparable. In two years of comparison, the 1997 brood supplemented production had about a 50% higher survival rate, but in the 1998 brood, the naturally produced smolts had about twice the survival of the supplemented fish. It is noteworthy that Neeley's (2002) analysis of hatchery and wild smolt survival using PIT tag data generally show comparable survival of hatchery and wild juveniles to McNary Dam.

These initial results should at least confirm that the extensive design, monitoring and evaluation, were appropriate and necessary to account for the annual variation expected in this study.

The YFP has a diversified monitoring and evaluation program designed and only a few measures were presented here. These examples indicated that:

- Harvest accounting indicates that harvest rates are being maintained at a low to moderate level, but catch for Tribal and non-Tribal peoples has increased.
- The distribution of spawning redds has paralleled the increased returns by stock.
- Run timings of natural and supplemented (hatchery reared) sub-stocks are very similar but that the natural stock has been slightly earlier in both years.

This program should be highly informative over time as it is the only new program developed with both a "hatchery" reference (newly developed traditional hatchery stock within the Cle Elum facility and to be assessed independently of the others stocks) and "wild" references (Naches and American substocks). One concern for this assessment is the capability to conduct equally complete assessments on the Naches and American stocks. The capability of downstream and upstream assessments in the Naches is more limited than in the Yakima and annual variations, just due to natural occurrences, will result in more variability in results for those stocks.

This summary was based on information reported in NPPC (1982), YFP (1996), Berg (2001), Bosch (2002), and Neeley (2002). The latter report was provided by YKFP following their review of an earlier draft of this section.

Mountain Snake Province

A 9. Idaho Supplementation Studies: Spring-run Chinook Supplementation in the Salmon and Clearwater Subbasins

Introduction

The Salmon and Clearwater subbasins support an important and diverse group of the Pacific Northwest's wild, indigenous salmonid populations. Many of them reside in habitat strongholds within large areas of designated wilderness and other roadless terrain. The two subbasins provide a core of remaining connected habitat for five species of salmonids: bull trout, westslope cutthroat trout, redband trout (sympatric with steelhead), stream-type chinook salmon, and summer steelhead (Lee et al. 1997, Thurow et al. 2000). They also support critical habitat for listed sockeye salmon, and large connected habitats for Pacific lamprey, white sturgeon, and a variety of other native nongame fishes.

Although resident salmonid populations within many of the Salmon and Clearwater subbasin's undeveloped areas are recognized as some of the strongest in the region, the ESA-listed salmon and steelhead in these areas are struggling to persist upstream of eight hydroelectric dams on the mainstem Columbia and Snake rivers and in the face of degraded or non-accessable habitat in many watersheds. Regional decision-makers have developed plans focusing on restoring habitats within degraded watersheds as an alternative to breaching lower Snake River dams as a restoration measure for anadromous salmonids. This is intended to increase in-subbasin survival rates of anadromous fish and improve habitat conditions for important populations of resident salmonids and other sensitive species within the subbasin.

In addition to these habitat actions, plans to conserve and restore salmon and steelhead populations involve using artificial production techniques. Artificial production varies by species and stock and includes captive rearing for the endangered Redfish Lake sockeye, conventional harvest-oriented production of spring chinook (Rapid River) and steelhead (Lower Snake River Compensation Program (LSRCP)), and supplementation production for spring/summer chinook (ISS project). Our review here is confined to the Idaho Supplementation Studies on spring/summer chinook. Supplementation activities for steelhead in the Salmon and Clearwater subbasins are not organized into a systematic and rigorous experimental design, but occur at smaller scales on specific populations.

Salmon River Subbasin

The Salmon Subbasin covers approximately 14,000 square miles or 16.7% of the land area of Idaho. Ten major hydrologic units (watersheds) occur within the subbasin: the Upper Salmon, Pahsimeroi, Middle Salmon-Panther, Lemhi, Upper Middle Fork Salmon, Lower Middle Fork Salmon, South Fork Salmon, Lower Salmon, and Little Salmon watersheds. The subbasin has nearly 1700 named streams with a combined length of nearly 17,000 stream miles. These streams flow from headwaters in the Beaverhead, Salmon River, Lemhi, Lost River, Sawtooth, and smaller mountain ranges to the mouth of the Salmon River at its confluence with Snake River in lower Hells Canyon. The largest of the major watersheds is the Upper Salmon, and the smallest the Little Salmon.

Public lands account for approximately 91 percent of the Salmon Subbasin, with most of this being in federal ownership and managed by seven National Forests or the Bureau of Land Management. Public lands within the subbasin are managed to produce wood products, forage for domestic livestock, and mineral commodities, and to provide recreation, wilderness, and terrestrial and aquatic habitats. Approximately nine percent of the subbasin land area is privately owned. Private lands are primarily in agricultural cultivation, and are concentrated in valley bottom areas within the upper and lower portions of the subbasin.

No year-round, total barriers to fish migration currently exist on the Salmon River and its larger tributaries, however total barriers exist on many smaller tributaries. Partial, total, and seasonal barriers to anadromous fish exist on Panther Creek in the form of acid mine drainage, and on the Lemhi, Pahsimeroi and upper Salmon rivers at water diversions for irrigation. Twenty minor tributaries contain dams that are used for numerous purposes such as irrigation, recreation and fish propagation (Salmon Subbasin Summary, 1990).

Two power dams were constructed on rivers in the Salmon Subbasin in the early 1900s but have since been removed. These were Sunbeam Dam on the mainstem Salmon River immediately upstream from the Yankee Fork confluence and a power dam on the lower Lemhi River. Sunbeam Dam, constructed in 1910 by the Golden Sunbeam Mining Company, remained intact until it was intentionally breached in 1934. Sunbeam Dam constituted a complete blockage for adult anadromous fish to the uppermost Salmon River subbasin for most of the period between 1911 and 1934. In 1934, the rock abutment on the south side of the dam was breached with explosives. A power dam blocked the lower Lemhi River in the 1920's and 30's, isolating the Lemhi basin except during high water periods when water bypassed the dam. A combination of the dam and hatchery and commercial take contributed to the collapse of the chinook stock and by the late 1930's the run had dwindled to about 200 fish. The power dam was removed in 1938 and fish runs began to rebuild until the 1960's. They have declined since, with only 7 redds found in a 1994 aerial survey of the Lemhi watershed (ISCC 1995).

Clearwater River Subbasin

The Clearwater River subbasin, lying immediately north of the Salmon River subbasin, drains approximately a 9,645 square mile area in north central Idaho. There are four major tributaries that drain into the mainstem Clearwater River: the Lochsa, Selway, South Fork Clearwater, and North Fork Clearwater Rivers. Dworshak Dam, constructed in 1972, is located two miles above the mouth of the North Fork Clearwater River where it blocks access to one of the most productive tributary systems for anadromous fish in the subbasin. It is the only major water regulating facility in the subbasin.

More than two thirds of the total acreage of the Clearwater subbasin is evergreen forests (over four million acres), largely in the mountainous eastern portion of the subbasin. The western third of the subbasin is part of the Columbia plateau and is comprised almost entirely of crop and pastureland. Most of the forested land within the Clearwater subbasin is owned by the federal government and managed by the USFS (over 3.5 million acres), but the state of Idaho, Potlatch Corporation, and Plum Creek Timber Company also own extensive forested tracts. The western half of the subbasin is primarily in the private ownership of small forest landowners and timber companies, as well as farming and ranching families and companies. Nez Perce Tribal lands are located primarily within or adjacent to Lewis, Nez Perce, and Idaho Counties within the current boundaries of the Nez Perce reservation.

Seventy dams currently exist within the boundaries of the Clearwater subbasin, the vast majority of which exist in the Lower Clearwater (56), although dams also currently exist in the Lower North Fork (3), Lolo/Middle Fork (5), and South Fork (6) areas. Of the 70 dams, descriptive data concerning the size, capacity and ownership is available for only 46; the remainder are thought to be small earthen structures with minimal storage capacity.

At 219 m in height with a reservoir approximately 54 miles long and a maximum depth of 194 m, Dworshak Dam is the largest straight axis concrete dam in the United States. Dworshak reservoir extends 54 miles into the North Fork Clearwater River Canyon and provides 3.453 million acre-feet of storage, making it the largest storage project within the Nez Perce Tribe ceded area and the state of Idaho (Idaho Department of Fish and Game and Nez Perce Tribe 1991; U.S. Army Corps of Engineers 1975). Located two miles above the mouth of the North Fork Clearwater River the dam blocked fish passage for anadromous fish to spawning habitat that could accommodate approximately 109,000 steelhead trout redds and 74,000 chinook salmon redds (U.S. Fish and Wildlife Service 1962). The dam also inundated 16,970 acres of terrestrial and riverine habitats at full pool (U.S. Army Corps of Engineers 1975).

Drawdowns for flood control may lower the surface elevation of Dworshak Reservoir 47 m and reduce surface area by as much as 52%. The reservoir has a mean retention time of 10.2 months and a mean annual discharge of 162 m^3/s (Falter 1982). High releases from the reservoir occur during spring run-off, during late summer when water is released for anadromous fish flows, and during the fall when the reservoir is lowered for flood control.

Numerous dams have been removed from the Clearwater subbasin that had substantial impacts on fisheries resources within the subbasin. Lewiston dam, constructed in 1927 on the lower Clearwater River near the present site of the Potlatch pulp mill (RM 4) and operated by Washington Water Power, virtually eliminated chinook salmon runs and substantially reduced steelhead runs into the Clearwater subbasin (Nez Perce Tribe and Idaho Department of Fish and Game 1990). Modifications were later made to Lewiston Dam to facilitate fish passage, and the dam was removed in 1973 as part of the Lower Granite Lock and Dam Project. A dam constructed in 1910 on the lower South Fork

Clearwater (RM 22) near the town of Harpster by Washington Water Power blocked anadromous salmon species from the South Fork Clearwater River. The dam formed a complete barrier to fish migration from 1911-1935 and from 1949-1963, when the dam was removed (Paradis et al. 1999b). A fish ladder was installed in the dam in 1935 and was destroyed in 1949 by high flows (Paradis et al. 1999b).

Chinook Salmon in the Salmon and Clearwater Subbasins

Two chinook salmon ESUs are recognized by the National Marine Fisheries Service (NMFS) under the Endangered Species Act, spring/summer and fall chinook salmon. Historical numbers of chinook salmon entering the Clearwater River subbasin are assumed to be substantial, but no documentation on actual numbers is available (Nez Perce Tribe and Idaho Department of Fish and Game 1990). Chapman (1981) estimated that 1.5 million smolts were produced annually from Clearwater chinook stocks resulting in 87,433 adults returning to the mouth of the Columbia River. The majority of historical chinook salmon production was thought to occur in major tributary systems of the Clearwater River (North, South, and Middle Forks), with less than 10% of total production in the mainstem reach (Clearwater National Forest 1997). Within the mainstem portion of the Clearwater River, the most substantial production of spring chinook salmon probably occurred in the Lolo and Potlatch Creek drainages (Clearwater National Forest 1997; Clearwater Basin Bull Trout Technical Advisory Team 1998b). Redd counts for chinook (spring/summer) have varied between approximately 50 and 400 over the last 35 years.

Re-introduction of spring chinook salmon following removal of the Lewiston Dam has resulted in naturally reproducing runs in Lolo Creek, and mainstems and tributaries of the Lochsa, Selway, and South Fork Clearwater Rivers (Larson and Mobrand 1992). Founding hatchery stocks used for spring chinook salmon re-introductions were primarily obtained from the Rapid River Hatchery (Kiefer et al. 1992; Nez Perce Tribe and Idaho Department of Fish and Game 1990). Initially however, spring chinook stocks imported for restoration came from Carson, Big White, Little White or other spring chinook captured at Bonneville dam (Nez Perce Tribe and Idaho Department of Fish and Game 1990). Genetic analyses confirm that existing natural spring chinook salmon in the Clearwater River subbasin are derived from reintroduced Snake River stocks (Matthews and Waples 1991). Consequently, spring chinook salmon within the Clearwater subbasin are excluded from the ESU encompassing other spring/summer stocks throughout the Snake River basin, but represent an important effort aimed at restoring an indigenous fish population to an area from which they had been extirpated.

Natural recolonized and re-introduced fall chinook salmon within the Clearwater subbasin are part of the Snake River evolutionarily significant unit (ESU) as defined by the ESA. As such, fall chinook salmon within the Clearwater subbasin represent an important metapopulation within the Snake River ESU. Maintenance and function of fall chinook salmon metapopulation dynamics within the Clearwater subbasin itself will play an important role in recovery of the Snake River ESU.

ISS Overview

The Idaho Department of Fish and Game (IDFG) spearheaded development of the Idaho Supplementation Studies to help define the potential role of supplementation in managing Idaho's anadromous fisheries and as a recovery tool for the basin (NPPC 1987), and to address questions identified in the Supplementation Technical Work Group (STWG) Five Year Workplan (STWG 1988). The goal of the Idaho Supplementation Studies is to evaluate various supplementation strategies for maintaining and rebuilding spring/summer chinook salmon populations in Idaho and to develop recommendations for using supplementation to rebuild naturally spawning populations.

The ISS project is an Idaho statewide research effort occurring throughout the Salmon and Clearwater subbasins. The study and all related research activities are operated under an “umbrella” agreement among four cooperating agencies: 1) IDFG (lead agency), 2) Nez Perce Tribe (NPT), 3) Shoshone-bannock Tribes (SBT), and 4) US Fish and Wildlife Service (USFWS). Due to the large geographic scope of this study, study streams were partitioned among four resource management entities for implementation. These include Idaho Department of Fish and Game (IDFG), Nez Perce Tribe (NPT), Shoshone-Bannock Tribe (SBT), and the U.S. Fish and Wildlife Service-Idaho Fishery Resource Office (USFWS). Approximately one-half of the study is being implemented by IDFG through the ISS contract with BPA. The Nez Perce Tribe and Shoshone-Bannock Tribe have similar commitments to ISS, each comprising approximately 20% of the study. Both of these components rely heavily on integration of existing or proposed tribal programs. The USFWS implements about ten percent of the project. The IDFG is the lead agency regarding project development, coordination, and implementation.

Projects directly involved in the ISS are:

Salmon Subbasin

1. **Project ID 198909800.** Idaho Supplementation Studies. **Sponsor:** Idaho Department of Fish and Game and Idaho Office of Species Conservation.

2. **Project ID 198909802.** Evaluate Salmon Supplementation Studies in Idaho Rivers- Nez Perce Tribe. **Sponsor:** Nez Perce Tribe.

3. **Project ID 198909803.** Salmon Supplementation Studies in Idaho- Shoshone-Bannock Tribes. **Sponsor:** Shoshone-Bannock Tribes.

4. **Project ID 199604300.** Johnson Creek Artificial Propagation Enhancement Project. **Sponsor:** Nez Perce Tribe

Clearwater Subbasin

5. **Project ID 198909801.** Evaluate Supplementation Studies in Idaho Rivers (ISS). **Sponsor:** U.S. Fish and Wildlife Service - Idaho Fishery Resource Office.

6. **Project ID 199005500.** Steelhead Supplementation Studies in Idaho Rivers. **Sponsor:** Idaho Department of Fish and Game and Idaho Office of Species Conservation.

The ISS coordinates field activities and data collection efforts with the Idaho Habitat/ Natural Production Monitoring project (199107300). The ISS also coordinates with and transfers data to projects in the Salmon River subbasin including the Monitoring Smolt Migration of Wild Snake River Spring/Summer Chinook Salmon (199102800), Salmon River Habitat Enhancement (9405000), and Salmon River Production Program (199705700). The ISS also works closely with the Lower Snake River Compensation Plan (LSRCP) to coordinate on hatchery supplementation treatments and evaluations.

ISS Study Design

The ISS study design called for a minimum of 15 years (three generations) of research (Bowles and Leitzinger 1991). Sampling was initiated in 1991, and implementation began in 1992. Supplementation effects were to be monitored and evaluated by comparing juvenile abundance and survival, adult fecundity, age structure, and genetic diversity in treatment and control (reference) streams of similar ecological parameters, however current pilot analyses were only possible on abundance of redds due to incomplete data on other parameters. The words “reference stream” are preferred by the ISAB because perfect “control streams” are not usually feasible; however, in reference to the ISS we use their choice, i.e., “control”. The study design called for three phases: **Phase I** was local broodstock development; **Phase II** was the treatment period, and **Phase III** the evaluation period. Each phase was anticipated to occur over a five-year duration, however the low adult returns experienced in the 1990s, slowed broodstock development and treatments in some study streams. This has resulted in many treatments being out-of-phase with the original study design.

Broodstock development for the ISS treatment streams did not follow the RASP guidelines of development from a local wild source. Instead, broodstocks were developed using local wild/natural adults crossed with hatchery-origin adults from the hatchery stock already being outplanted into the treatment stream at the inception of the ISS program. Progeny from these initial crosses that returned as adults were again crossed with wild/natural adults and progeny from this second set of crosses were released (all marked) as the first set of ISS smolt releases and treatments.

The mixed hatchery and wild/natural heritage of the broodstocks means that a straightforward evaluation of the fitness effects of supplementation treatments will not be possible in the forthcoming **Phase III** portion of the study. Additionally, because not all hatchery-origin adults were marked at the time the ISS broodstocks were being developed, the wild/natural adults used to establish the local broodstock could have been from several sources including the indigenous wild chinook populations, the hatchery stock used at that time in the treatment stream, or a hatchery-origin adult from another conventional hatchery that strayed into the treatment stream.

These difficulties and other critical issues raised by the ISRP in its FY2002 review of the Idaho Supplementation Studies in the Mountain Snake provincial review led the ISS staff to revisit its experimental design for the ISS effort. They have recently completed an updated experimental design and protocol for statistical analysis (Lutch et al. 2003). The protocol attempts to specifically address ISRP concerns about the staggered timetable, partial treatment streams, statistical power, and statistical analysis in the face of straying by conventional hatchery fish into reference and treatment streams.

Analytical difficulties caused by the staggered timetable have been addressed in two ways by IDFG researchers. First, all treatment streams will move into the **Phase III** evaluation portion of the study in the spring of 2004, after the last smolt releases occur. This allows 12 of the 15 treatment streams to receive enough smolt releases to be classified within the study design as having received a full **Phase II** treatment. The remaining thee streams will be classified as having only a partial treatment. Presently only 5 of the 15 treatment streams have received a full **Phase II** treatment. Second, in conducting preliminary analyses, IDFG researchers discovered that calendar year did not provide a meaningful measure of time for statistical purposes due to the staggered timetable of **Phase II** treatments imposed by the difficulties of establishing local broodstocks (p. 14; Lutch et al. 2003). Consequently, IDFG researchers used an alternative measure of time, where positive integers (1,2,3, …8 as needed) denote the first, second, third, etc, years where supplementation produced fish could have come back and reproduced in the treatment stream (also called the Time II period). Years prior to that (Time I), where supplementation produced fish could not have come back and reproduced in the treatment stream (i.e., **Phase I** and early **Phase II** of study design), were coded as -8, -7, …., -1, and 0.

The initial ISS Experimental Design was completed and published in 1991. Baseline data collection and development of supplementation broodstocks (**Phase I**) began in 1991. Over a period of about five years, supplementation broodstocks were developed for seven hatchery trap/release locations as identified in the experimental design. These are:

Artificial Production Facilities

1. Sawtooth Fish Hatchery – Upper Salmon River
2. Pahsimeroi Fish Hatchery – Pahsimeroi River
3. McCall Fish Hatchery – South Fork Salmon River

Clearwater Fish Hatchery Satellites

4. Crooked River
5. Red River
6. Powell (Colt-killed Creek)
7. Clear Creek – Kooskia National Fish Hatchery

As adult fish began to return from the **Phase I** supplementation broodstock juvenile releases, the project progressed into **Phase II**. **Phase II** utilizes the returning adults to supplement natural origin recruits in treatment streams and maintains supplementation broodstocks for juvenile production and release. Juvenile fish releases through brood year 1996 include 1,281,755 fish in the Clearwater River basin and 1,954,048 fish in the Salmon River basin.

This project is now transitioning from **Phase II** to **Phase III**, monitoring the effects of supplementation. In **Phase III,** juvenile releases from supplementation broodstocks are to be terminated. At present, this will occur in the spring of 2004, when the last smolt releases occur (Figure 4.1; Lutch et al. 2003). In **Phase III**, returning hatchery-origin adults from prior juvenile releases are expected to supplement spawning of natural origin recruits. Monitoring of production and productivity response variables in reference and treatment streams will occur from 2004 through 2014, or approximately for two generations. IDFG researchers felt it necessary to track the treatment (and reference) populations for a minimum of two generations in order to assess whether the abundance increase achieved during the treatment phase was maintained in the non-supplemented population. However, researchers expect to collect data beyond 2014 as well.

Summary of ISS Results To Date

Lutch et al. (2002) summarize the most recent results from the ISS in their updated report on experimental and statistical design. The original study design for ISS included 20 treatment and 11 reference streams. Current design is for 16 treatment and 14 reference streams (Figure A9.1 and Table A9.1; Lutch et al. 2003). Changes in original and present design are primarily related to low adult returns in the 1990s and difficulties in establishing treatment broodstocks from each local population.

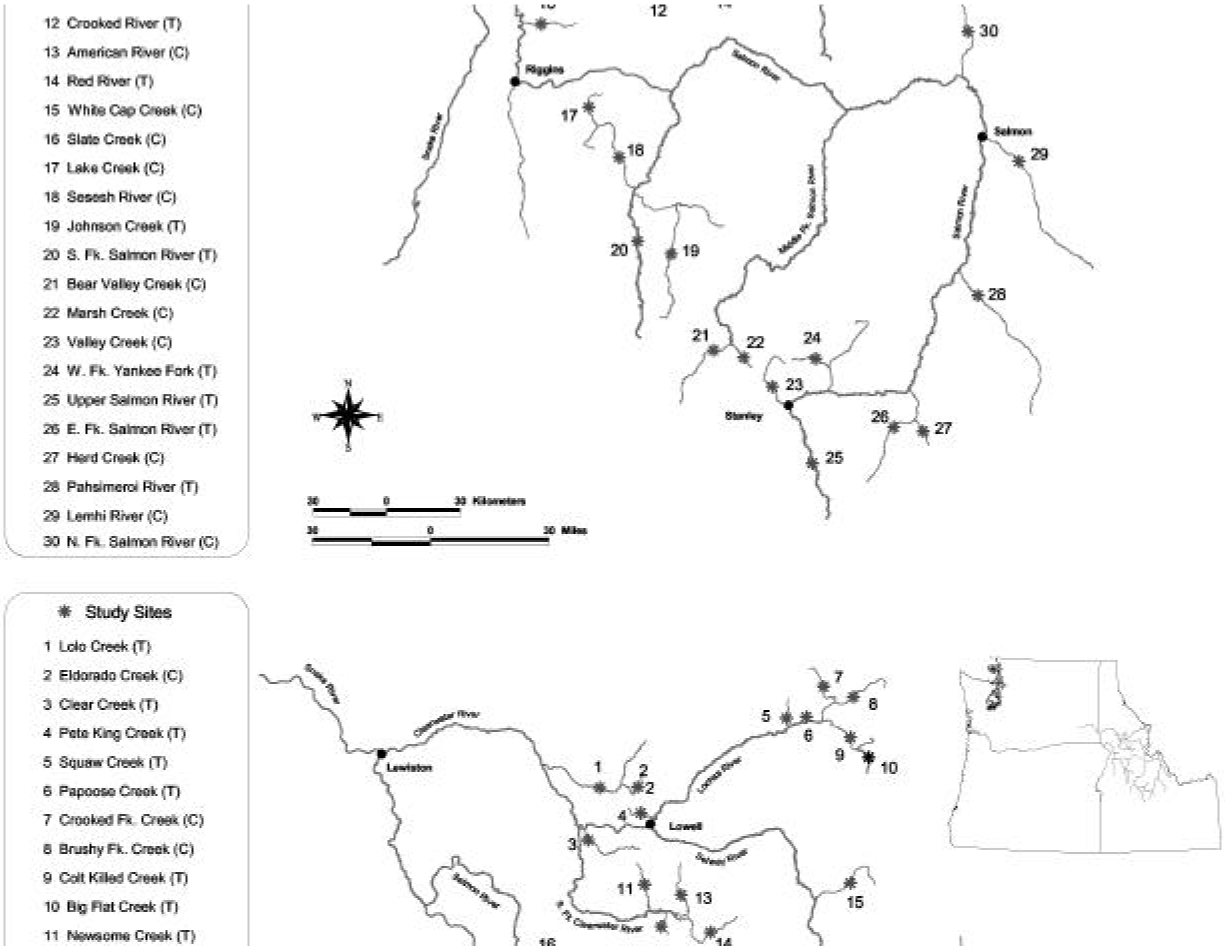

Figure A9.1. From Lutch et al. (2003) showing the current treatment and control streams for the Idaho Supplementation Studies.

The new design also attempts to account for lack of implementation of the full design by incorporating a partial treatment category for streams that have received less than 50% of the treatments prescribed in the original study (Table A9.2; Lutch et al. 2003). IDFG believed that it would be unwise to assume that streams receiving only a few treatments were directly comparable to streams receiving nearly all prescribed treatments. Preliminary analyses of the ISS treatment effects (Lutch et al. 2003) uses redd count data, expressed as redds/km, as it generated the most complete dataset. Unanalyzed, but incomplete, data exist on carcass recoveries, weir counts, juvenile emigration/abundance, and parr density/abundance.

The ISRP identified straying to be a problem that needed additional attention in the ISS study and the analysis protocol. ISS cooperators agreed with this assessment. For treatment streams, strays were defined as non-ISS hatchery-produced fish that strayed into ISS study reaches. For control streams, all hatchery-origin chinook (supplementation and general production were considered strays).

Table A9.1. Number of treatments completed to date in ISS study streams. Partial treatment refers to streams that have received <50% of annual treatments prescribed in the original study design. From Lutch et al. (2003).

	Status through Brood Year 1999		
Treatment Stream	**Number of treatments**	**Percent treatment**	**Treatment designation**
Clearwater Basin			
Lolo Creek	3	33	Partial
Newsome Creek	4	40	Partial
Crooked River	4	44	Partial
Red River	7	78	Treatment
Clear Creek	5	56	Treatment
Pete King Creek	3	33	Partial
Squaw Creek	4	44	Partial
Papoose Creek	3	33	Partial
Colt Killed Creek	4	44	Partial
Big Flat Creek	2	22	Partial
American River	1	11	Partial
Salmon Basin			
SF Salmon River	9	100	Treatment
Pahsimeroi River	7	78	Treatment
EF Salmon River	3	33	Partial
WF Yankee Fork	1	11	Partial
Upper Salmon River	9	100	Treatment

The estimated proportion of non-ISS fish recovered annually in each stream suggests that substantial straying is occurring in many ISS study reaches (Table A9.2; Lutch et al. 2003). In the Salmon River subbasin, straying averaged more than 25% in two treatment streams. Treatment streams in the Clearwater River subbasin experienced even higher rates of straying, with estimates exceeding 50%. Because most Clearwater treatment streams are located adjacent to satellite conventional hatchery facilities that maintain LSRCP mitigation and other subbasin activities, the result is disturbing but not surprising. IDFG suspected that these estimates were fairly representative of the straying component to the ISS project.

IDFG ran a preliminary analysis on the relationship between staying and redd abundance for a limited number of streams. Not surprisingly, they found a positive relationship between total redd abundance and straying. This was particularly evident in streams where the most complete carcass data were available, such as Crooked Fork Creek, Red River, and the South Fork Salmon River. They then compared an analysis of variance of the data with and without straying as a covariate. Results of the test of equality of slopes indicated that the supplementation treatment by stray interaction was statistically nonsignificant ($F_{2,45} = 0.297$, $p = 0.774$), which suggested that the slopes of the lines across all study streams were not significantly different. Using ANCOVA, they found the covariate was significant ($F_{1,47} = 40.26$, $p = 0.000$) and the supplementation treatment and time interaction not significant ($F_{12,47}=1.489$, $p=0.162$). When the covariate is omitted, the test of interaction is also not significant ($F_{12,48}=1.191$, $p = 0.317$). Based on this preliminary analysis, the investigators reached the conclusion that there is a relationship between redd production and straying, while no statistically significant effect on the treatment by time interaction was observed for the 11 streams analyzed. In further statistical analyses, the investigators dropped the effect of straying from the model. The investigators note and the ISAB agree that this conclusion is preliminary, may not hold in the analysis of additional data, and data on straying needs to be collected on all ISS streams.

Table A9.2. Average proportion of non-ISS chinook salmon carcasses recovered in ISS study streams during carcass surveys. N = the number of years with covariate estimates out of a possible of seven. ND = no data. From Lutch et al. (2003).

Subbasin	**Study Stream**	**Category**	**N**	**Proportion Stray**
Clearwater River	American River	Treatment	7	0.61
	Big Flat Creek	Treatment	7	0.63
	Brushy Fork Creek	Control	7	0.44
	Clear Creek	Treatment	7	0.31
	Colt Killed Creek	Treatment	6	0.64
	Crooked Fork Creek	Control	7	0.58
	Crooked River	Treatment	7	0.30
	Eldorado Creek	Control	3	0.22
	Herd Creek	Treatment	4	0.08
	Lolo Creek	Treatment	7	0.38
	Newsome Creek	Treatment	5	0.44
	Papoose	Treatment	7	0.41
	Pete King Creek	Treatment	1	0
	Red River	Treatment	7	0.43
	Squaw Creek	Treatment	3	0.33
	White Cap Creek	Control		ND
Salmon River	Bear Valley Creek	Control	7	0
	EF Salmon River	Treatment	2	0
	Johnson Creek	Control	7	0.02
	Lake Creek	Control	7	0.05
	Lemhi River	Treatment	6	0
	Marsh Creek	Control	5	0.01
	NF Salmon River	Treatment	3	0
	Pahsimeroi River	Treatment	4	0.27
	Secesh River	Control	7	0.05
	Slate Creek	Control	3	0.21
	SF Salmon River	Treatment	7	0.67
	Upper Salmon River	Treatment	4	0
	Valley Creek	Treatment	6	0
	WF Yankee Fork	Treatment	2	0

The next major refinement of the ISS study design was an attempt to standardize for the treatment type by assigning treatment streams to the categories: full, partial or control, and for the differing time schedules among the many treatment and controls streams, due to the staggering of broodstock development, and treatment duration resulting from the low adult returns in the 1990s. Results of the prototype Partial F tests of fixed effects yielded a highly significant treatment by time interaction, suggesting that supplementation affected redd counts (Table A9.3). Scrutinizing the least squared means (Table A9.4) and differences between least squared means (Table A9.5), the investigators reached the preliminary conclusion that the significance of the treatment by time interaction results largely from an increase in the partially treated category from Time I to Time II. In general, it appears that at the inception of the ISS study partially treated streams had fewer redds per km than control streams, while fully treated streams had more. Thus far, it appears that supplementation increased redds per km in partially treated streams, which now surpass redds per km in control streams, on average. Again, the investigators note and the ISAB agree that this conclusion is preliminary and may not hold in the analysis of additional data. In particular, it may not be appropriate to ignore the effect of strays in future analyses.

Table A9.3. Type 3 tests of fixed effects from the prototype analysis of ISS redds per kilometer data. From Lutch et al. (2003).

Effect	Numerator DF	Denominator DF	F-Value	Pr>F
Treatment	2	19	0.82	0.4572
Time	1	14	4.15	0.0610
Treatment x Time	2	240	18.11	<0.0001

Table A9.4. Least squared means associated with control, partial, and fully treated ISS streams during Time I and Time II of the ISS project. From Lutch et al. (2003).

Treatment	Time	Estimate	Standard Error	Degrees of Freedom	t value	Pr>|t|
Control	1	0.2420	0.1011	240	2.39	0.0175
Control	2	0.3416	0.09723	240	3.51	0.0005
Partial	1	0.1229	0.1084	240	1.13	0.2582
Partial	2	0.5605	0.1091	240	5.14	<0.0001
Treatment	1	0.3991	0.1314	240	3.04	0.0027
Treatment	2	0.4510	0.1219	240	3.70	0.0003

Table A9.5. Differences of Least Squared Means. From Lutch et al. (2003).

Effect	Treatment	Time	Treatment	Time	Estimate	Error	DF	t Value	Pr > |t|
Treatment x Time	Control	1	Control	2	-0.09961	0.1004	240	-0.99	0.3222
Treatment x Time	Control	1	Partial	1	0.1191	0.09942	240	1.2	0.232
Treatment x Time	Control	1	Partial	2	-0.3184	0.1354	240	-2.35	0.0195
Treatment x Time	Control	1	Treatment	1	-0.157	0.1161	240	-1.35	0.1773
Treatment x Time	Control	1	Treatment	2	-0.209	0.1416	240	-1.48	0.1413
Treatment x Time	Control	2	Partial	1	0.2187	0.1324	240	1.65	0.0997
Treatment x Time	Control	2	Partial	2	-0.2188	0.09705	240	-2.25	0.0251
Treatment x Time	Control	2	Treatment	1	-0.05743	0.1484	240	-0.39	0.6992
Treatment x Time	Control	2	Treatment	2	-0.1094	0.1067	240	-1.03	0.3062
Treatment x Time	Partial	1	Partial	2	-0.4376	0.1015	240	-4.31	<.0001
Treatment x Time	Partial	1	Treatment	1	-0.2762	0.1263	240	-2.19	0.0298
Treatment x Time	Partial	1	Treatment	2	-0.3281	0.1483	240	-2.21	0.0278
Treatment x Time	Partial	2	Treatment	1	0.1614	0.1577	240	1.02	0.3072
Treatment x Time	Partial	2	Treatment	2	0.1094	0.1194	240	0.92	0.3604
Treatment x Time	Treatment	1	Treatment	2	-0.05195	0.1133	240	-0.46	0.6469

Lutch et al. (2003) caution that these results and interpretations are preliminary. Adults from ISS Phase II juvenile treatments will continue to return through calendar year 2007, and thus are not reflected in these data. The preliminary interpretations above are presented by the investigators to demonstrate that a viable prototype statistical analysis has been formulated that is capable of handling the unique challenges associated with the ISS study (e.g., differing levels of treatment and timing of treatments), resulting from deviations from the original study design.

Bringing the ISS to Conclusion

The ISS cooperators recommend ceasing development of supplementation broodstock for all treatment streams with Brood Year 2002. Projected treatments through BY02 will increase the number of treated (i.e. >50% treated) streams compared to partially treated streams (Table A9.6, from Lutch et al. 2003). Rather than staggering treatment among selected streams over a specific period, ISS cooperators felt that ceasing treatment simultaneously would likely reduce annual variation and error associated with differences in mainstem passage and ocean productivity. Broodstock created through 2002 will be released into ISS treatment streams through spring 2004 as prescribed in the study design (Bowles and Leitzinger, 1991). Transition from **Phase II** (Supplementation) to **Phase III** (Evaluation) will occur once all brood year releases are completed.

Table A9.6. Current and expected levels of supplementation releases in ISS treatment streams from BY91-BY99. Partial treatment designation categorizes streams that have received <50% of annual treatments originally defined in the study design.*= no releases since BY93. From Lutch et al. (2003).

	Status Through BY99			Predicted Status Through BY02		
Treatment Stream	**Number of Treatments**	**Percent Treatment**	**Treatment Designation**	**Number of Treatments**	**Percent Treatment**	**Treatment Designation**
Clearwater Basin						
Lolo Cr	3	33	Partial	6	50	Treatment
Newsome Cr	4	40	Partial	7	54	Treatment
Crooked R	4	44	Partial	7	58	Treatment
Red R	7	78	Treatment	10	83	Treatment
Clear Cr	5	56	Treatment	8	67	Treatment
Pete King Cr	3	33	Partial	6	50	Treatment
Squaw Cr	4	44	Partial	7	58	Treatment
Papoose Cr	3	33	Partial	6	50	Treatment
Colt Killed Cr	4	44	Partial	7	58	Treatment
Big Flat Cr	2	22	Partial	2	17	Partial
Salmon Basin						
SF Salmon R	9	100	Treatment	11	92	Treatment
Pahsimeroi R	7	78	Treatment	10	83	Treatment
EF Salmon R	3	33	Partial	3*	25	Partial
WF Yankee Fork	1	11	Partial	1*	8	Partial
Upper Salmon R	9	100	Treatment	12	100	Treatment

Final Summary of ISS Study

It is clear that the recent ISRP reviews of the ISS suite of projects have led to a major re-evaluation of the study design and development of an analysis protocol. The project nears an important juncture (spring 2004), where it transitions from **Phase II** supplementation treatments into the **Phase III** evaluation period where supplementation treatments cease. The objectives of **Phase III** include determination of the efficacy of the ISS supplementation effort by documenting whether or not any increased abundances in the supplemented populations are sustainable over the two-generation Phase III evaluation period.

The pilot analysis conducted by Lutch et al. (2002) was limited to redd abundance per mile on a small number of streams where carcass data were collected annually and could be used to estimate the abundance of strays. The ability to meaningfully analyze the ISS for one parameter, abundance of redds, at the end of Phase III depends critically on complete carcass data for determination of strays on all streams. This data collection should be a top priority of the study. It appears doubtful that sufficient data will be collected on other parameters, e.g. juvenile emigration/abundance, and parr density/abundance, to allow for analysis, leaving only redd abundance adjusted for the effect of strays as a measure of treatment effect.

The investigators report preliminary analyses at this time using the prototype analytical protocol. These preliminary analyses on incomplete and subjectively selected data indicate that supplemented streams may have experienced an increase in abundance relative to control streams. The ISAB cautions that even this weak conclusion is premature because it is partially based on selected data and for analytical reasons because the prototype statistical analysis considers "control", "partial treatment" and "treatment" streams as fixed categories when they are not. Also, it seems likely that the effects of strays cannot be ignored in the final analysis. The ISS has features more characteristic of an observational study that limits making cause and effect inferences. Also, a primary confounding issue in interpretation of the results is the de facto supplementation arising from straying of non-ISS fish into both treatment and control streams. The best possible interpretation, as suggested in the preliminary analyses, is that the *de facto* supplementation affects the response profiles of redd abundance on all streams equally (profiles are parallel) and the effects of strays stay the same in the future. However, this seems to be far from the original objectives of the ISS study, namely to contrast the profiles of naturally producing fish (that had no supplementation during **Phase II or Phase III**) with the profiles of naturally producing fish (that had supplementation in **Phase II**, but no supplementation in **Phase III**). The current and future de facto supplementation seems to severely compromise the chances of meeting the original objective of the ISS. It seems unlikely that the ISS will contribute the compelling evidence for or against supplementation that managers in the region are likely expecting unless significant changes are made in the design of Phase III.

There is a need to use DNA level microsatellite analysis to identify parentage relationships between spawning adults, outmigrating smolts, and adults that return to spawn in the next generation (including the use of assignment tests) in order to separate non-ISS strays from natural production within distinct tributary systems. A second step, and subset of this analysis, would be to then separate ISS supplementation fish from natural-origin fish in the same system using the same methods. The principal investigators should evaluate the current status of chinook tissue collections throughout the ISS populations and stream types (treatment, control) to determine if collections are sufficient to allow this type of DNA analysis. If not, project sponsors should assess the overall project and identify locations, opportunities, and schedules (and budgets) that will provide for this critically needed analysis.

Captive Broodstock Programs

A 10. Redfish Lake Sockeye Salmon Captive Broodstock Program

This summary is based on information in BPA project proposal 199107200: Redfish Lake Sockeye Salmon Captive Broodstock Program. A portion of the 2002 Mountain Snake Provincial Review, Frost et al. (2002), Kline and Willard (2001), and Kline (personal communication).

Precipitous declines of Snake River sockeye salmon prompted the Idaho Department of Fish and Game (IDFG) to initiate a captive broodstock program in 1991 to attempt to avoid the species extinction. The program is to reestablish sockeye salmon runs to Stanley Basin waters and to provide for sport and treaty harvest opportunities. In the near-term, the program is focused on preventing further population loss, maintaining population genetic integrity, and rebuilding the population numbers.

Anadromous adult sockeye salmon, wild Redfish Lake out-migrants, and residual sockeye salmon adults have been captured and used to develop broodstocks at the IDFG Eagle Fish Hatchery and at NMFS facilities in Washington State. The program generates hatchery-produced eggs, juveniles, and adults for supplementation to Stanley Basin waters. Fish culture attributes, juvenile out-migration and adult return are monitored and evaluated. Through 2002 , the IDFG and NMFS hatchery programs produced in excess of 860,000 pre-smolts, 158,000 smolts, 880 adults, and 325,000 eyed-eggs for reintroduction to Stanley Basin lakes and tributary streams. From this production, approximately 300,000 hatchery-produced, juvenile sockeye salmon have emigrated from Stanley Basin waters.

In 1999, seven age 3 hatchery-produced adult sockeye salmon returned to the Stanley Basin to spawn (six males and one female). In 2000, 257 sockeye salmon returned to collection facilities on Redfish Lake Creek and the upper Salmon River at the IDFG Sawtooth Fish Hatchery. In 2001, 26 and in 2002, 22 (7 at Sawtooth Hatchery weir, 8 at Redfish Lake Creek and 7 observed but not collected below the Sawtooth weir).

Broodstock Development and Spawning

Broodstock was developed using 16 wild, anadromous adult sockeye salmon that returned to the Stanley Basin and were captured from 1991 to 1998; 26 residual sockeye salmon adults captured in 1992, 1993, and 1995; and 886 wild, outmigrating smolts from Redfish Lake captured from 1991 to1993. (Table A10.1).

Table A10.1. Redfish Lake Sockeye Salmon Captive Broodstock Program collection history for wild, Redfish Lake sockeye salmon.

Collection year	Anadromous adults	Residual adults	Smolts
1991	4 (3 male, 1 female)		759
1992	1 male	5 (4 male, 1 female)	79
1993	8 (6 male, 2 female)	18 (16 males, 2 females)	48
1994	1 female		
1995		3 males	
1996	1 female		
1997			
1998	1 male		

The sockeye salmon captive broodstock program began spawning in 1991. Wild anadromous females were spawned in 1991, 1993, 1994, and 1996. Egg survival to the eyed stage for wild female has averaged 76%. Hatchery-produced adult sockeye salmon have been spawned yearly since 1994. Egg survival to the eyed stage of development has been variable (39% to 73%) averaging 55%. Spawning results for the history of the program are presented in Table A10.2. Cryopreserved milt is frequently incorporated in spawning designs to avoid inbreeding and to maximize genetic diversity. IDFG spawning plans undergo review by NMFS Northwest Fisheries Science Center and University of Idaho research staff.

Table A10.2. Eagle Fish Hatchery spawning of wild anadromous, wild outmigrant, wild residual, and hatchery-produced adult sockeye salmon.

Spawn Year	Female brood year and origin	Green eggs taken	Eyed-eggs produced	Mean fecundity	Egg survival to eyed stage
1991	Wild anadromous (1 female)	2,177	1,978	2,177	91%
1992	Wild Residual (1)	36	36	-	100%
1993	Wild anadromous (2 females)	6,320	3,699	3,160	58%
	OM91 wild outmigrants	32,956	9,656	2,059	29%
	Wild residuals (2)	317	292	158	92%
1994	BY91 hatchery-produced	466,830	256,756	1,995	55%
	Wild anadromous (1 female)	2,896	2,780	2,896	96%
1995	BY92 hatchery-produced residuals	3,289	1,349	1,644	41%
	OM92 wild outmigrants	2,079	1,156	2,079	56%
	OM93 wild outmigrants	1,080	501	1,080	46%
1996	BY93 hatchery-produced	180,000	109,000	2,118	61%
1996	Wild anadromous (1 female)	2,067	1,756	2,067	85%
1997	BY94 hatchery-produced	253,673	152,760	2,205	60%
1998	BY96 hatchery-produced	32,375	15,580	1,199	48%
1999	BY96 hatchery-produced anadromous	1,469	1,370	1,469	93%
	BY96 hatchery-produced	160,436	61,798	1,976	39%
2000	BY97 hatchery-produced	377,550	214,298	2,924	57%
	BY96 hatchery-produced anadromous	44,151	32,022	2,772	73%
	BY98 hatchery-produced	11,603	6,727	1,527	58%
		Total	**873,514**		

Milt from all wild anadromous sockeye salmon (16 males), wild outmigrants brought into the program between 1991 and 1993, residual sockeye salmon, and unique hatchery-produced adults has been cryopreserved. Cryopreserved milt is archived at the Eagle Fish Hatchery, the University of Idaho, and Washington State University. Currently, 1,489 0.5 ml straws of sockeye salmon milt representing 357 unique males are stored at the Eagle Fish Hatchery, and a comparable number of 0.5 ml straws are stored at University of Idaho and Washington State University facilities.

Egg and Fish Reintroductions

Four strategies to reintroduce sockeye to Stanley Basin lakes are being tested: maturing adults are released to spawn naturally, eyed eggs are planted in lake shore gravel, pre-smolts are released into lakes for over wintering prior to a natural spring migration, and smolts are released into the Salmon River.

Eyed-egg planting. Beginning in 1996 eyed eggs produced at the IDFG Eagle Fish Hatchery and the NMFS-operated Big Beef Creek Hatchery in Washington State have been planted in Redfish, Alturas, and Pettit lakes (Table A10.3).

Table A10.3. Redfish Lake Sockeye Salmon Captive Broodstock Program eyed-egg release history and estimated hatch results.

Release year	Release location	No. of eggs planted	Estimated hatch
1996	Redfish Lake	105,000	97%
1997	Redfish Lake	85,378	98%
	Alturas Lake	20,389	72%
1999	Pettit Lake	20,311	74%
2000	Pettit Lake	65,200	79%
2002	Pettit Lake	30,924	n/a
	Total	**327,202**	

Pre-smolt planting. The first releases age 0, hatchery-produced juvenile sockeye to Stanley Basin lakes occurred in 1994. Since that time, Redfish Lake has received pre-smolt plants in each year the program has operated. Three pre-smolt release strategies have been employed: a mid-summer direct-lake release, a fall direct-lake release, and a fall release from a net pen environment. In 1995 and 1997, Pettit and Alturas lakes were incorporated in annual release and evaluation activities. Both lakes have received mid-summer and fall, direct-lake introductions of pre-smolts. Pre-smolt release groups are generated from eggs produced at the IDFG Eagle Fish Hatchery and the NMFS-operated Big Beef Creek Hatchery. Rearing to release takes place at the IDFG Eagle and Sawtooth fish hatcheries. All fish are adipose fin-clipped and a portion PIT-tagged to facilitate over winter survival and out migration evaluations.

The pre-smolt releases are summarized in Table A10.4.

Table A10.4. Redfish Lake Sockeye Salmon Captive Broodstock Program pre-smolt releases.

Release Lake	Release Strategy	Release Date	Number Released	Number PIT-tagged	Mean Release Wt.
Redfish	Net pen	8/3/94	11,130	1,904	8.2 g
Redfish	Fall direct-lake	11/23/94	2,989	854	8.1 g
Redfish	Net pen	10/10/95	28,163	1,721	11.4 g
Redfish	Summer direct-lake	6/29/95	27,179	1,731	5.8 g
Redfish	Fall direct-lake	10/5,10/95	27,703	2,520	16.1 g
Pettit	Summer direct-lake	7/27/95	8,527	861	7.4 g
Redfish	Net pen	10/7/96	1,932	1,932	22.0 g
Redfish	Net pen	10/21/97	62,907	2,596	21.1 g
Redfish	Summer direct-lake	7/14/97	21,036	1,990	9.6 g
Redfish	Fall direct-lake	10/15/97	68,379	2,010	21.0 g
Pettit	Summer direct-lake	7/1/97	8,643	1,336	8.7 g
Alturas	Fall direct-lake	10/16/97	72,496	1,861	21.0 g
Alturas	Summer direct-lake	7/15/97	22,250	2,032	8.4 g
Redfish	Net pen	10/1/98	55,830	2,973	14.4 g
Redfish	Fall direct-release	10/14/98	39,418	1,206	10.6 g
Pettit	Summer direct-lake	7/15/98	7,246	1,501	9.8 g
Alturas	Fall direct-lake	10/14/98	39,377	1,246	10.3 g
Redfish	Fall direct-lake	10/6/99	23,886	1,560	9.7 g
Pettit	Fall direct-lake	10/6/99	3,430	2,009	10.4
Alturas	Fall direct-lake	10/6/99	12,955	1,559	10.8 g
Redfish	Fall direct-lake	10/11/00	48,051	-	10.8 g
Pettit	Summer direct-lake	7/31/00	6,007	-	2.9 g & 8.5 g
Pettit	Fall direct-lake	10/11/00	6,067	-	13.9 g
Alturas	Summer direct-lake	7/31/00	5,986	-	2.9 g & 8.5 g
Alturas	Fall direct-lake	10/11/00	6,003	-	12.8 g
Redfish	Fall direct-lake	10/8/01	41,529	-	10.8 g
Redfish	Net Pen	10/10/01	41,474		30.0 g
Pettit	Fall direct-lake	10/9/01	4,993	-	15.4 g
Pettit	Summer direct lake	7/27/01	3,059	-	14.4 g
Pettit	Summer direct lake	7/31/01	2,998	-	4.0 g
Alturas	Fall direct lake	10/9/01	5,990	-	14.0 g
Alturas	Summer direct lake	7/27/01	3,064	-	14.5 g
Alturas	Summer direct lake	7/31/01	3,059	-	4.0
Redfish	Summer direct-lake	8/28/02	31,000	-	11.4 g
Redfish	Summer direct-lake	8/29/02	30,500	-	11.4 g
Alturas	Summer direct-lake	8/27/02	6,123	-	10.6 g
Pettit	Summer direct-lake	8/27/02	7,805	-	11.4 g
Redfish	Fall direct-lake	10/8/02	45,001	-	15.3 g
Pettit	Fall direct-lake	10/8/02	19,981	-	14.8 g
		Total	**864,166**		

Smolt planting. Hatchery-produced smolt releases were incorporated in the release design and evaluation in 1995. To date, in excess of 159,000 smolts have been released to Stanley Basin waters. Two release locations have been used: Redfish Lake Creek and the upper Salmon River. Smolt release groups are generated from eggs produced at the IDFG Eagle Fish Hatchery and the NMFS-operated Big Beef Creek Hatchery. Rearing through release takes place at the IDFG Eagle and Sawtooth fish hatcheries and Oregon Department of Fish and Wildlife's Bonneville Fish Hatchery. All fish are adipose fin-clipped and a portion PIT-tagged to facilitate over winter survival and out migration evaluations. In addition, fish may receive additional fin marks or coded wire tags to facilitate adult return evaluations.

Smolt releases are summarized in Table A10.5.

Table A10.5. Redfish Lake Sockeye Salmon Captive Broodstock Program smolt releases.

Release location	Date released	Number released	Number PIT-tagged	Mean release weight
Redfish Lake Creek	4/21/95	3,794	1,371	177.5 g
Redfish Lake Creek	5/2/96	11,545	1,990	50.0 g
Redfish Lake Creek	4/28, 5/4/98	37,583	2,000	26.5 g & 63.5 g
Upper Salmon River	4/28, 5/4/98	44,032	1,999	26.5 g & 63.5 g
Redfish Lake Creek	5/5/99	4,859	400	25.4 g
Upper Salmon River	5/4/99	4,859	400	25.4 g
Redfish Lake Creek	5/9/00	148	148	258 g
Redfish Lake Creek	5/2/01	13,915	1,000	49.4 g
Redfish Lake Creek	5/7/02	38,672	995	27.6 g
	Total	**159,344**		

Pre-spawn adult planting. Pre-spawn adult sockeye salmon from the Sockeye Salmon Captive Broodstock Program were first released to Stanley Basin waters in 1993. Since that time, adult releases have occurred in 1994, 1996, 1997, 1999, 2000, 2001, and 2002. For release years 1993, 1994, 1996, and 1997, all pre-spawn adults released for natural spawning were reared through release (full-term) at IDFG and NMFS hatcheries. From 1999 through 2002, release groups consisted of full-term hatchery adults and hatchery-origin anadromous adults. Prior to releasing adults for natural spawning, a sub-set of adults are fitted with ultrasonic or radio transmitters to facilitate tracking and spawning evaluations.

A summary of adult sockeye salmon releases is presented in Table A10.6.

Table A10.6. Redfish Lake Sockeye Salmon Captive Broodstock Program pre-spawn adult release history and estimated redd construction.

Release Lake	Rearing origin	Date released	Number released	Number of suspected redds observed
Redfish	Full-term hatchery	1993	20	
Redfish	Full-term hatchery	1994	65	One behavioral observation
Redfish	Full-term hatchery	1996	120	30 suspected redds
Redfish	Full-term hatchery	1997	80	30 suspected redds
Pettit	Full-term hatchery	1997	20	1 suspected redd
Alturas	Full-term hatchery	1997	20	Test digs only
Redfish	Full-term hatchery	1999	18	8 suspected redds
	Hatchery-produced anadromous	1999	3	
Redfish	Full-term hatchery	2000	46	20 to 30 suspected redds
Redfish	Hatchery-produced anadromous	2000	120	
Pettit	Full-term hatchery	2000	0	Redds suspected but not visible
Pettit	Hatchery-produced anadromous	2000	28	
Alturas	Full-term hatchery	2000	25	14 to 19 suspected redds
Alturas	Hatchery-produced anadromous	2000	52	
Redfish	Full-term hatchery	2001	65	12 to 15 areas of excavation observed
Redfish	Hatchery-produced anadromous	2001	14	
Redfish	Full-term hatchery	2002	178	10 areas of excavation observed
Redfish	Hatchery-produced anadromous	2002	12	
		Total	**886**	

Juvenile outmigrant. Juvenile outmigration monitoring is used to estimate over winter survival and out migration for sockeye salmon reintroduced to Redfish, Alturas, and Pettit lakes as pre-smolts. The IDFG maintains and operates the juvenile outmigration monitoring facility on the outlet of Redfish Lake. Trapping history for the Redfish Lake Creek site is presented below. Alturas and Pettit lake monitoring is the responsibility of the Shoshone-Bannock Tribes (Project No. 199107100) and summarized in Table A10.7. For perspective, Table A10.7 summarizes pre-smolt, smolt, pre-spawn adult, and eyed-egg supplementation efforts. The relative contribution of all release options is presented in this table.

Table A10.7. Redfish Lake Sockeye Salmon Captive Broodstock Program egg and fish reintroduction history and corresponding estimated outmigration.

REDFISH LAKE							
Year	No. of pre-smolts planted	Estimated pre-smolt out-migration	No. of smolts planted	No. of pre-spawn adults planted	No. of eyed-eggs planted	Estimated unmarked out-migration	Total estimated out-migration
1993				20		569	569
1994	14,119			65		1,820	1,820
1995	83,045	823	3,794			357	4,974
1996	1,932	12,075	11,545	120	105,000	923	24,543
1997	152,322	401		80	85,378	304	705
1998	95,248	28,435	81,615			2,799	112,849
1999	23,886	22,425	9,718	21		1,936	34,079
2000	48,051	7,055	148	166		302	7,505
2001	83,003	9,616	13,915	79		110	23,641
2002	106,501	20,239	38,672	190		3,461	62,372
Totals	**608,107**	**101,069**	**159,407**	**741**	**190,378**	**12,581**	**273,057**

ALTURAS LAKE							
Year	No. of pre-smolts planted	Estimated pre-smolt out-migration	No. of smolts planted	No. of pre-spawn adults planted	No. of eyed-eggs planted	Estimated unmarked out-migration	Total estimated out-migration
1993- 96							
1997	94,746			20	20,389		
1998	39,377	30,000					30,000
1999	12,955	12,000				1,000	13,000
2000	11,989	4,300		77			4,300
2001	12,113	5,010					5,010
2002	6,123	3,674				6,176	9,850
Totals	**177,303**	**54,984**		**97**	**20,389**	**7,176**	**62,160**

PETTIT LAKE							
Year	No. of pre-smolts planted	Estimated pre-smolt out-migration	No. of smolts planted	No. of pre-spawn adults planted	No. of eyed-eggs planted	Estimated unmarked out-migration	Total estimated out-migration
1993 - 94							
1995	8,527						
1996		3,200					3,200
1997	8,643			20			
1998	7,246	400					400
1999	3,430	2,800			20,311		2,800
2000	12,074	1,600		28	65,200		1,600
2001	11,050	1,969				13	1,982
2002	27,786	1,803			30,924	1,607	3,410
Totals	**50,970**	**11,772**		**48**	**116,435**	**1,620**	**13,392**

ALL LAKES COMBINED							
Year	No. of pre-smolts planted	Estimated pre-smolt out-migration	No. of smolts planted	No. of pre-spawn adults planted	No. of eyed-eggs planted	Estimated unmarked out-migration	Total estimated out-migration
1993				20		569	569
1994	14,119			65		1,820	1,820
1995	91,572	823	3,794			357	4,974
1996	1,932	15,275	11,545	120	105,000	923	27,743
1997	255,711	401		120	105,767	304	705
1998	141,871	58,835	81,615			2,799	143,249
1999	40,271	37,225	9,718	21	20,311	2,936	49,879
2000	72,114	12,955	148	271	65,200	302	13,405
2001	106,166	16,595	13,915	79		123	30,633
2002	140,410	25,716	38,672	190	30,924	11,244	75,632
Totals	**864,166**	**167,825**	**159,407**	**886**	**327,202**	**21,377**	**348,609**

Both unclipped and fin-clipped sockeye salmon smolts emigrate from Redfish Lake. Since no wild, anadromous adults spawned in Redfish Lake after 1989, unmarked smolts emigrating from Redfish Lake after 1992 are presumably the progeny of residual sockeye salmon. Pre-spawn adults were first planted in Redfish Lake in 1993. However, successful redd construction was not observed until 1996. Age 1 smolts produced from 1996 spawning events would have emigrated from Redfish Lake in 1998. Eyed-eggs were first planted in Redfish Lake in 1996. Smolts produced from this release strategy would have out-migrated in 1998 as well. Therefore, the unmarked smolts observed from 1993 through 1997 are not attributed to pre-spawn adult or eyed-egg releases.

During the period of time when wild smolt outmigration was not influenced by the hatchery program, emigration ranged from a high of 4,500 fish in 1991 to a low of 304 smolts in 1997. In 1998 and 1999, unmarked smolt outmigration was estimated at approximately 2,800 and 1,900 fish, respectively. For age 1 smolts, these two outmigration years correspond to captive broodstock program spawn years 1996 and 1997; two years where pre-spawn adult and eyed-egg releases were employed. Considering the observed downward trend in wild outmigration numbers between 1993 and 1997, the increase observed in 1998 and 1999 is most likely attributable to eyed-egg and pre-spawn release strategies. This tentative conclusion is reinforced because the number of unmarked smolts fell off drastically in outmigration 2000 (approximately 300 outmigrants estimated). This was an out migration year not supplemented with eyed-egg or pre-spawn adult releases.

Of the three pre-smolt release options used to date (summer direct-lake, fall direct-lake and fall release from net pens), the direct summer option has been the least successful (all lakes). Over winter survival and outmigration from Redfish Lake fall direct-lake release groups has been consistently better than what has been observed for summer direct-lake and net pen release groups. In addition, Alturas and Pettit lake outmigrants produced from fall direct-lake release groups have performed consistently well. These results are now shaping the development of annual release plans for the captive broodstock program. While summer direct-lake releases have not been entirely abandoned, emphasis is being placed on fall pre-smolt releases. At the same time, an effort is being made to examine why summer pre-smolt releases were less successful. The IDFG and Shoshone-Bannock Tribes are working collaboratively with University of Idaho researchers to build a baseline of fish condition information for different stages in the life history of hatchery-produced sockeye salmon (e.g., at planting and outmigration).

Smolt releases generate the greatest proportion of juvenile detections through the migration corridor. In other words, smolt releases are more successful when it comes to getting the greatest number of juveniles downstream in relation to the number of fish released by strategy. However, the program’s technical oversight committee has been reluctant to over prioritize this option to the point where it creates an imbalance in the program’s “spread-the-risk” planting philosophy. The concern remains that sockeye salmon released as smolts might not have the same opportunity to imprint as fish produced from eyed-egg and pre-spawn adult plants or released to lakes as pre-smolts. Accordingly, fish released as smolts might not have the same ability to home and return to spawning waters in Idaho. However, the fact remains that 72% of the 264 hatchery-produced anadromous adults that have returned to the program were produced by smolt release strategies.

Adult Returns to the Program

Six hatchery-produced age-3 jack males and one age-3 jill sockeye salmon returned to Idaho in August and September 1999. All originated from smolts release from the upper Salmon River and to Redfish Lake Creek on April 28 and May 4, 1998. Fish were produced by spawning at the Big Beef Creek Hatchery. Eyed-eggs were transferred to the Oregon Department of Fish and Wildlife Bonneville Fish Hatchery for hatch and rearing to release.

In 2000, 257 anadromous sockeye salmon returned to the Sawtooth Basin. Traps on Redfish Lake Creek and the upper Salmon River at the Sawtooth Fish Hatchery intercepted 119 and 124 adults, respectively. Additionally, 14 adult sockeye salmon were observed immediately downstream of the Sawtooth Fish Hatchery trap. Fish were captured between July 22, and September 15, 2000. These adult sockeye salmon originated from a variety of release options including: 1) 1996 pre-spawn adult and eyed-egg releases in Redfish Lake, 2) 1997 pre-smolt releases in Redfish, Alturas, and Pettit lakes, and 3) 1998 smolt releases in Redfish Lake Creek and the upper Salmon River. The 1998 smolt release consisted of fish reared at the Sawtooth Fish Hatchery and at the Bonneville Fish Hatchery.

One hundred-ninety of the 243 fish handled and examined in 2000 were produced from spawning performed at the Big Beef Creek Hatchery. Eyed-eggs were transferred to the Oregon Department of Fish and Wildlife Bonneville Fish Hatchery for hatch and rearing to release. Fish were released to Redfish Lake Creek and the upper Salmon River as smolts in 1998.

In 2001, 26 sockeye salmon returned to the Stanley basin and in 2002, 22. Seven salmon were captured at Sawtooth, eight at Redfish Lake Creek, and seven were observed below the Sawtooth trap but not collected.

Ten, four, and six, un-marked adults have returned to the Redfish Lake Creek weir or Sawtooth trap in 2000, 2001, and 2002 respectively. The origin of the un-marked adults is yet to be validated. Tissue samples have been collected from all adults spawned in Idaho and Washington hatcheries as well as from anadromous adults released for natural spawning. Beginning in 2000, tissue samples have been collected from all un-marked outmigrants from Stanley Basin lakes. Parentage assignment using nDNA markers should begin to be available in FY2004.

The strategy of maintaining the broodstocks, and rearing progeny for reintroduction, at multiple locations is to avoid catastrophic loss owing to mechanical failures or diseases at a hatchery. This risk management strategy was useful in 2002 when more than 43,000 sockeye salmon smolts being reared at Bonneville Hatchery near Cascade Locks were destroyed because INH (infectious hematopoietic necrosis) virus was detected in fingerling pre-smolts in April.

A 11. Grande Ronde Spring-run Chinook Salmon

This summary is based on information in BPA project proposal 199801001: Grande Ronde basin spring chinook captive broodstock program. A portion of the 2002 Blue Mountain Provincial Review.

In response to severely declining runs of chinook salmon in the Grande Ronde Basin a captive broodstock program was initiated to attempt to prevent extirpation of endemic chinook populations in the Lostine River (LR), upper Grande Ronde River (GR) and Catherine Creek (CC).

The Grande Ronde basin once supported large runs of chinook salmon with estimated escapements in excess of 10,000 as recently as the late 1950's. Catherine Creek and Grande Ronde and Lostine rivers were historically three of the most productive populations in the Grande Ronde basin. Escapement levels in these three rivers dropped to alarmingly low levels in 1994 and 1995. Progeny-to-parent ratios have been below 1.0 for the past eight completed broodyears.

This captive broodstock program was initiated in the Grande Ronde basin in 1995. Up to 500 naturally produced parr are collected annually from each stream. Eight cohorts (1994-2001) have been collected from Catherine Creek and Lostine River (Table A11.1). Only six cohorts have been collected from Grande Ronde River (1994, 1996-1998, 2000, 2001) because of a lack of fish in the river in 1996 and 2000. These juveniles are reared to the smolt stage at Lookingglass Fish Hatchery (LFH) under either an accelerated or simulated natural pre-smolt growth regime. For the 1994-1999 cohorts, two-thirds of these smolts were transferred to Bonneville Fish Hatchery (BOH) and reared in freshwater and one-third to NOAA-Fisheries Manchester Marine Laboratory (MML) and reared in saltwater. Beginning with the 2000 cohort, one half of the fish have been sent to each post-smolt rearing facility.

Table A11.1. Number of parr collected for the Captive Broodstock Program, number removed from the captive population due to spawning, bacterial kidney disease (BKD), other diseases, operational causes and other causes, and the number remaining in captivity for each cohort, as of 31 December 2002.

		Causes of mortality					
Cohort	Number collected	Number spawned	BKD	Other Diseases	Operational causes	Other causes	Number remaining
1994	1107	621	188	40	101	157	0
1995	981	513	253	22	47	146	0
1996	1501	1012	233	26	12	218	0
1997	1500	1082	260	31	23	104	0
1998	1498	914	269	49	22	114	130
1999	1003	285	15	93	52	32	526
2000	1508	65	18	10	13	25	1377
2001	1461	0	0	6	1	6	1448

At maturity, saltwater adults are transported from MML to BOH where all fish are spawned. Eggs are incubated at Oxbow Fish Hatchery (OFH) to the eyed stage when they are transferred to Irrigon Fish Hatchery (IFH), where they hatch. Fry are transported to LFH for rearing to the smolt stage. Resulting F_1 smolts are acclimated at and released into the stream of parental origin.

Juveniles reared in captivity to adults have been spawned from 1998-2002 (Table A11.2). Full production is intended to provide sufficient smolts to ensure threshold escapement levels of 150 spawners in each parental stream. Therefore, release levels are based on management goals and the number of wild spawners present. Other potential release strategies include outplanting of adults, eggs or parr produced in excess of smolt needs, directly into unseeded historic production areas within the Grande Ronde basin. Parr were released in 2002 and 2003 and probably will be released in 2004.

In 1996 and 1997, males matured but there were no females with which to spawn them. Therefore, their sperm was collected and cryopreserved for use when live males of the appropriate stock, treatment and cohort are unavailable. In 1996, 89 males matured and 287 males matured in 1997.

Table A11.2. Number of males and females that matured and the number of eggs produced for each year in which fish matured and the year and number of smolts/parr released into parental streams from each spawn.

Spawn year	Mature fish			Smolts	
	Males	Females	Number of eggs	Year released	Number released
1996	89	0	0	--	0
1997	287	0	0	--	0
1998	308	120	162,341	2000	74,374
1999	565	307	511,507	2001	272,226
2000	664	460	757,848	2002	512,990
2001	630	478	929,099	2003	457,660
2002	329	361	592,318	2004	350,009*

*estimated number of smolts that will be released in 2004.

In 1998, 120 females were spawned and sperm was collected from 308 males (used to fertilize eggs or cryopreserved). 162,341 eggs were taken. 93,683 survived to the eyed stage (57.7% survival) and 74,374 (45.8% survival) were released as smolts. Age 3 jacks returned from this release in 2001 and age 4 adults in 2002.

In 1999, 307 females were spawned and sperm was collected from 565 males. 511,507 eggs were taken. 380,842 survived to the eyed stage (74.5% survival) and 272,226 (79.4% eyed egg-smolt survival) smolts were released. Jacks returned from this release in 2002.

The 2000 spawning included fish from all age classes (3-6) and is a likely indication of the numbers that we can expect in the future, unless survival to adulthood changes. In

2000, 460 females were spawned and sperm was collected from 664 males. 757,848 eggs were taken. 600,170 survived to the eyed stage (79.2% survival) and 512,990 (85.5% eyed egg-smolt survival) smolts/parr were released.

In 2001, 478 females were spawned and sperm was collected from 630 males. 929,099 eggs were taken. 817,697 survived to the eyed stage (88.0% survival) and 457,660 (56.0% eyed egg-smolt survival) smolts/parr were released.

In 2002, 361 females and 329 males were spawned (we had a bacterial kidney disease outbreak that influenced survival to maturation). 592,318 eggs were taken. 531,625 survived to the eyed stage (89.8% survival). Approximately 350,009 parr/smolts from this cohort are anticipated being released (65.8% eyed egg-smolt survival).

In March, Captive Broodstock offspring are transported to acclimation facilities located within the area of their parent's natal stream where wild fish spawn. In April, after a 14-30 day period of acclimation, fish are released into the stream, volitionally at first, with the remaining fish being forced out. Four cohorts of F_1's have been released and two groups of age 3 fish (jacks) have returned (2001 and 2002) and one group of age 4 fish (2002). Additional years of fish returning to the streams are necessary to evaluate survival rates. However, the return rates of 0.2-0.8% of 1998 cohort fish (ages 3 and 4, only) are viewed as encouraging.

The entire cycle, from captive broodstock parr collection to return of F_1 fish spawning in the wild, should take approximately seven (5-11) years. For example, fish collected in September 1995 may spawn at age 5 in September 1999 and the resulting progeny would be released as smolts in the spring of 2001 and may return to spawn in 2004 at the age of 5 years. For the purpose of clarifying the terminology associated with the monitoring and evaluation plan, we have divided this cycle into four phases, each comprised of shorter periods. The Captive Juvenile Phase begins at collection and ends when fish are transported as smolts to BOH or MML and is composed of two periods: pre-smolt growth and smoltification. The Captive Adult Phase begins at transfer to BOH or MML and continues until the fish have been spawned or die. It is composed of three shorter periods: post-smolt growth, maturation and spawning. The F_1 Generation Phase runs from fertilization of eggs from captive fish through the death of the fish from these embryos. This phase is composed of the incubation, juvenile rearing, smolt release, post-smolt growth, maturation and spawning periods. The F_2 Generation Phase begins once eggs from F_1 generation females are fertilized and ends when fish from these embryos die. This phase is composed of the pre-smolt, smolt, post-smolt growth, adult return and spawning periods.

The sponsor's summary conclusions are:

Initial Field Collections for establishing broodstock

1. Parr collections of 500 fish per stream generally were met
2. Accelerated growth pre-smolts produced larger smolts but grew slower than expected
3. Parr-to-smolt survival was above 95%

Broodstock Performance

1. Smolt-to-spawn survival was variable but slightly above 55%
2. Sex ratio was 1:1
3. Saltwater groups grew slower than freshwater groups
4. Pre-smolt rearing regime affected age at maturity but not size at maturity
5. Males matured earlier than expected - most at age 3
6. Females matured later than expected - fewer age 4 and more age 5
7. Captive broodstock spawn about 3 weeks later than wild fish
8. Mean fecundity and the number of eyed eggs was lower (~ 50%) than expected for ages 4 and 5 females

F_1 Performance

1. Survival to eye-up was greater than the 75% expected
2. Egg-to-smolt survival was generally lower than the 80% expected
3. Smolt production was generally below the 150,000 expected but smolt production has been limited at times by management objectives
4. Outmigration timing of captive broodstock progeny was similar to that of wild salmon, but survival to Snake/Columbia River dams was lower than wild salmon.
5. F_1 (ages 3 and 4, only) return rate ranged from 0.2% (Grande Ronde) to 0.8% (Lostine River) for 1998 cohort.

A 12. Tucannon Spring-run Chinook Salmon

This summary is based on information in BPA project proposal 200001900: Tucannon River Spring Chinook Captive Broodstock Program. A portion of the 2002 Blue Mountain Provincial Review, Bumgarner and Gallinat (2001), and Gallinat and Varney (2003).

Adult returns of spring-run chinook salmon to the Tucannon river ranged from 400 - 750 between 1985 and 1993. In 1994 adult escapement was under 150, and in 1995 was estimated to be only 54 salmon. In 1997, WDFW and the co-managers believed that extreme intervention (captive broodstock) was called for to prevent extinction. This captive broodstock project was planned to be short-term (ending in 2008) to reduce potential negative genetic risks.

This program is to produce additional hatchery smolts for release into the Tucannon River between 2002 and 2008, concurrently with the existing supplementation program begun in 1985. The supplementation program requires collection of 100 salmon from the Tucannon River (50 natural and 50 hatchery), to produce 132,000 smolts for release at 15 fish/lb. Alone, that supplementation program has not been able to prevent the continued decline in abundance of Tucannon River spring-run chinook.

The captive broodstock program is projected to produce approximately 290,000 eggs on an annual basis once three brood years have obtained maturity. With an estimated egg viability of 70% and estimated fry to smolt survival rate of 70-80%, WDFW has estimated 150,000 smolts (15 fish/lb) will be available for release into the Tucannon River from Curl Lake Acclimation Pond. Smolt production of that magnitude will double the current spring chinook smolt releases into the Tucannon River. Based on smolt to adult survival rates of hatchery spring chinook in the Tucannon River, WDFW estimates that 240-280 adult fish will return from each brood year. Combined with the standard supplementation program, hatchery origin spring chinook runs in the Tucannon River should reach 500-600 fish/year between 2005 and 2010. These returning captive brood origin adults will be left in the river to spawn naturally to increase natural production in the Tucannon River.

In this captive broodstock program 80 progeny from between 15-30 distinct family groups (1200 individuals/brood year) generated by the standard supplementation program will be retained and reared to maturity at Lyons Ferry Hatchery. Groups of half-sib crosses were combined into single family units, so in-family matings would not occur in the future. At one year of age, 30 fish/family will be retained for final rearing (450/brood year). Selection of families for captive broodstock is based on low ELISA titers for BKD, and parental origin. Wild x wild, and wild x hatchery crosses will be selected over hatchery x hatchery crosses. Captive broodstock collections are intended from the 1997-2001 brood years. As of January 1, 2003, there were 11 BY 1998, 194 BY 1999, 314 BY 2000, and 447 BY 2001 fish rearing at Lyons Ferry hatchery.

The 2002 eggtake from the 1997 BY (Age 5) was 13,176 eggs from 10 ripe females. Egg survival was 22%. Mean fecundity based on the 5 fully spawned females was 1,803 eggs/female. The 2002 eggtake from the 1998 brood year (Age 4) was 143,709 eggs from 93 ripe females. Egg survival was 29%. Mean fecundity based on the 81 fully spawned females was 1,650 eggs/female. The 2002 eggtake from the 1999 BY (Age 3) was 19,659 eggs from 18 ripe females. Egg survival was 55%. Mean fecundity based on the 18 fully spawned fish was 1,092 eggs/female. These progeny will be marked for evaluation and then released in the Tucannon River.

One success that was achieved compared to other existing captive broodstock program was maturation timing. Because of the similar maturation/spawn timing, some captive brood females are crossed with wild (unmarked) males from the supplementation program with the remaining females crossed with captive males. WDFW believes this will be beneficial to the overall spring chinook stock by maintaining the genetic integrity for the future.

The first adult returns (jacks) from the captive broodstock program are expected to return to the Tucannon River in 2003.

A 13. Captive Rearing Initiative for Salmon River Chinook Salmon

The IDFG initiated the Captive Rearing Project for Salmon River Chinook Salmon to investigate a strategy of preventing cohort collapse by providing captive-reared adult spawners to the natural environment. This summary is based on BPA project proposal 199700100: Captive Rearing Project for Salmon River Chinook Salmon and a portion of the 2002 Mountain Snake Provincial Review and BPA reports (Hassemer et al. 1999, 2001).

The project depends on developing culture techniques to produce adult salmon with behavioral, morphological, and physiological characteristics to successfully interact with and breed with wild individuals. Field monitoring is used to document behavioral interactions, spawn timing, success of redds spawned by captive-reared individuals, and to determine if changes in culture technique result in the desired changes in reproductive behavior or performance. The chinook project was initiated in 1995 with the collection of brood year 1994 progeny from the Lemhi, East Fork Salmon, and West Fork Yankee Fork Salmon rivers.

Fish Collections

Captive individuals for this project are the progeny of naturally spawning adults. From 1995 through 1998, parr were collected. Parr initiated feeding and survived, but by 1999 it became apparent there were limitations because of disease, parasite infestations, and slow growth in wild caught juveniles. In 1999 and 2000 eyed-eggs were hydraulically pumped from natural redds to provide ongoing broodstock for the program. The complete collection history for the program is presented in Table A13.1.

Table A13.1. Collection history for the Captive Rearing Project for Salmon River Chinook Salmon. Numbers of fish or eggs collected (or produced from in-hatchery spawning) are indicated by brood year and stock.

Stock	Brood Year								
	BY94	BY95	BY96	BY97	BY98	BY99	BY00	BY01	BY02
Lemhi NP	200	163	178	147	191				
Lemhi NE						264			
Lemhi SN									
WFYF NP	214		113	210	229				
WFYF NE							304	272	308
WFYF SN						300			
EFSR NP	201		5		185				
EFSR NE						143	503	311	328
EFSR SN					304	91			

NP and NE refer to rearing groups sourced as natural parr and eyed-eggs, respectively.
SN refers to safety net rearing groups sourced from in-hatchery spawning.
Lemhi, WFYF, and EFSR refer to the Lemhi, West Fork Yankee Fork Salmon, and the East Fork Salmon rivers.

To evaluate reproduction by the captive broodstock and to provide eggs for program continuity in the event low wild/natural adult chinook salmon escapement to target streams, some captive individuals were spawned in captivity. The majority of eggs produced in this fashion are returned to target streams as part of a hatch box program. Some progeny were retained and added to rearing groups.

Fish Rearing

After collection, fish are reared in freshwater at the Eagle Fish Hatchery until they reach the smolt stage. At the smolt stage most of each cohort (>70%) is transferred to NOAA-Fisheries Manchester Marine Laboratory seawater rearing facility, Manchester, Washington.

For parr, survival from collection to transfer exceeded 95%. For eyed-eggs, survival from collection through hatch has exceeded 96% for collection years 1999 and 2000. Survival from ponding through transfer to seawater for natural egg groups averaged 92% for these two collection years.

In the first years of this project fish were distributed 50% to freshwater and 50% to seawater. At that time it was not known whether freshwater or seawater culture would produce captive-reared adult chinook salmon with the competence to spawn naturally. As fish from the first two cohorts collected (BY94 and BY95) began to sexually mature four to five years later, program staff decided saltwater rearing provided a better product. Numbers of smolts transferred to NOAA Fisheries for seawater rearing are presented in Table A13.2.

Table A13.2. Seawater transfer history for the Captive Rearing Project for Salmon River Chinook Salmon. Numbers of fish or eggs transferred are indicated by brood year and stock.

Stock	Brood Year								
	BY94	BY95	BY96	BY97	BY98	BY99	BY00	BY01	BY02
Lemhi NP	75	68	110	102	158				
Lemhi NE						210			
Lemhi SN									
WFYF NP	87		60	165	193				
WFYF NE							203	n/a	n/a
WFYF SN						242			
EFSR NP	75		5		145				
EFSR NE						113	379	n/a	n/a
EFSR SN					229	65			

NP and NE refer to rearing groups sourced as natural parr and eyed-eggs, respectively.
SN refers to safety net rearing groups sourced from in-hatchery spawning.
Lemhi, WFYF, and EFSR refer to the Lemhi, West Fork Yankee Fork Salmon, and the East Fork Salmon rivers.

Growth, Survival and Sexual Maturation.

Fish within each brood year attain sexual maturity over a three-year period at ages 3 through 5 (additionally, some males mature at age 2). Because multiple cohorts from each stream population are being reared at any point in time, the sexually maturing group each year consists of age 2 to age 5 fish. Beginning in May of each year, fish are sorted to isolate maturing fish. Maturation is primarily assessed by physical inspection although non-lethal genetic sex assays and ultrasound examinations have been used to compliment the inspections.

The growth rates of brood year 1994 chinook salmon reared in freshwater and saltwater were similar, but maturing fish from each group were generally smaller than their ocean reared conspecifics. Inventories conducted between June and September 1996-1998 indicated that captive-reared fish had grown to approximately 200, 380, and 520 mm fork length in each year, respectively. By 1999 only freshwater reared individuals remained in culture, and were approximately 500 mm fork length, indicating that little additional growth was realized between the fourth and fifth year of life. In contrast, ocean reared spring/summer chinook salmon returning to the Columbia River basin between 1991 and 1996 generally averaged 740-800 mm fork length (Fryer 1998). This apparent difference in size between captive- and ocean-reared chinook salmon may affect the ability of captive-reared individuals to compete for mates, defend territories, and avoid predation (Hassemer et al. 2001).

Most captive-reared chinook salmon from brood year 1994 matured at age 3 or 4, with relatively little precocial (age 2) development regardless of rearing history. However, age 3 maturation was exclusively male and age 4 maturation predominantly female. Precocial male development was low in the East Fork Salmon River and West Fork Yankee Fork Salmon River groups, ranging between 8% and 12% of the mature males in each group. Lemhi River males had a much higher precocial rate, 61.5%. Several confounding factors are suggested by program staff to account for this observation. First, very few males from this group matured, suggesting that males from the Lemhi River may have had a higher mortality rate than males from the other groups. Second, the overall percentages of precocial males in the three groups were very similar. Precocial development was 2.8% in the West Fork Yankee Fork Salmon River group (6 precocial out of 216 fish brought into the program), 3.5% in the East Fork Salmon River group (7 of 199), and 4.1% in the Lemhi River (8 of 193). This also suggests Lemhi River males may have experienced higher mortality than those in the other groups (Hassemer et al. 2001).

Mortality in the brood year 1994 fish was relatively evenly split between causes related to culture activities (52.5%) and reproductive maturity (45.8%). Approximately 50% of the mortality associated with fish culture was attributable to a flow blockage that occurred in 1996. Disease and unexplained mortality accounted for less than 2% of the observed cohort mortality. Sixteen percent of the ’94 brood year were spawned in culture to provide evaluation of gamete quality, eggs for hatch boxes, and backup to wild egg collections. Thirty percent of the ’94 brood year were released to spawn naturally (Hassemer et al. 2001).

Reproduction Evaluations

To evaluate reproduction (e.g., maturation timing, gamete quality, egg survival to eyed stage of development) by captive-reared adult chinook salmon, individuals were spawned at the Eagle Fish Hatchery. Milt from captive-reared male chinook salmon has been cryo-preserved and stored at the Eagle Fish hatchery since 1997. Fecundity and egg survival from captive females for spawn years 1998, through 2002 are presented in Table A13.3.

Table A13.3. Summary of spawning at the Eagle Fish Hatchery. NP, NE, and SN refer to natural parr, natural egg, and safety net groups. LR, YF, and EFSR refer to the Lemhi, West Fork Yankee Fork Salmon, and East Fork Salmon rivers.

Spawn Year	Stock and rearing history	No. of females spawned	Mean Fecundity	Mean egg survival to the eyed stage	No. of eyed eggs produced
1998	LR, NP-FW	3	953	48.5%	2,799
	LR, NP-SW	4	2,367	92.0%	8,005
	YF, NP-FW	1	2,377	8.8%	168
	YF, NP-SW	2	2,070	83.3%	3397
	EF, NP-FW	3	1,590	32.5%[1] 20.1%[2]	4,225[1] 1,148[2]
	EF, NP-SW	10	2,080	78.5%[1] 20.6%[2]	11,363[1] 1,104[2]
1999	YF, NP-SW	2	1,644	79.0%	2,597
	EF, NP-FW	1	391	10.5%[2]	41[2]
	EF, NP-SW	1	2,596	41.9%[2]	1,088[2]
2000	YF, NP-SW	1	1,323	95.7%	1,266
2001	LR, NP-?	26	23	37.9%	8,154
2002	LR, NP-?	47	42	66.5%	47,977

1. Fertilized with fresh sperm; 2. Fertilized with cryo-preserved sperm

Captive-reared adult chinook salmon originating from naturally produced parr are smaller in size, produce fewer eggs, and have reduced fertilization compared to their anadromous counterparts, or conventionally reared hatchery-origin individuals with an anadromous component to their life-cycle. Egg quality is greater in saltwater reared individuals than in freshwater reared individuals and sperm quality is greater in fresh milt than in cryo-preserved milt.

Table A13.4. Summary of captive chinook salmon eyed-egg transfers and hatching rates for instream and streamside incubators at Lemhi River (LR), West Fork Yankee Fork Salmon River (WFYF), and East Fork Salmon River (EFSR) sites.

Year planted and incubation location	No. of eyed-eggs transferred	Dates transferred	No. of eyed-eggs planted	Estimated hatching rate
1998, WFYF	3,451	11/2/98	3,393	92.1%
1998, LR – Hayden Ck	9,324	11/2/98	9,320	75.0%
1998, EFSR	15,240	11/2, 7/98	15,240	91.04%
1998, EFSR – Big Boulder Ck	2,039	11/2, 7/98	2,039	62.3%
1999, WFYF	2,297	10/13/99	2,297	86.0%
1999, EFSR	1,038	11/2/99	1,038	No data, hatch box vandalized
2000, WFYF	1,266	11/8/00	1,266	82.7%
2001, LR - Bear Valley Ck	8,130	10/18, 11/1/01	8,130	pending
2002, LR – Hayden Ck	47,997	10/16, 23, 31/02	47,997	pending

Natural Spawning Performance Evaluations

Releases of chinook salmon are summarized in Table A13.5. A summary of reproductive performance evaluations, by year, follows.

Table A13.5. Summary of maturing, chinook salmon reintroductions for natural spawning. Lemhi River (LR), West Fork Yankee Fork Salmon River (WFYF), and East Fork Salmon River (EFSR) captive chinook salmon. M, F, and U refer to male, female, and unknown sex.

Year Adults Planted	Planting Location	Brood Year	Sex	Number Planted
1997	Lemhi River	BY94	M	1
	West Fork Yankee Fork	BY94	M	4
	East Fork Salmon River	BY94	M	4
1998	Lemhi River	BY94	F	34
		BY95	M	10
	Bear Valley Creek	BY94	F	15
		BY95	M	9
	West Fork Yankee Fork	BY94	F	35
		BY95	M	9
1999	Bear Valley Creek	BY94	F	9
		BY95	F	24
		BY95	M	1
		BY96	M	16
		BY97	M	12
	East Fork Salmon River	BY94	F	6
		BY94	M	1
2000	Big Springs Creek	BY94	F	1
		BY95	F	15
		BY96	F	32
		BY96	M	4
		BY97	M	20
2001	West Fork Yankee Fork	BY96	F	4
		BY97	F	42
		BY98	M	43
2002	West Fork Yankee Fork	BY97	F	27
		BY98	F	34
		BY98	U	6
		BY98	M	17
		BY99	M	76
		BY00	M	56
	East Fork Salmon River	BY98	F	30
		BY98	M	13
		BY98	U	3
		BY99	M	45
		BY00	M	40

<u>1997</u> In 1997 maturing brood year 1994 chinook salmon males fitted with radio transmitters were reintroduced to the Lemhi River (1 male), the West Fork Yankee Fork Salmon River (4 males), and the East Fork Salmon River (4 males) on August 1, 1997. The single Lemhi River male remained in the area of release for approximately two weeks. On August 19, the fish was located approximately 1.0 km downstream of the release site. On August 29 the fish was observed at an upstream location in close

proximity to three redds with attending adult females, one redd with a pair of fish, and one completed redd. On September 10 the radio signal was lost.

All West Fork Yankee Fork males were located on the first day of radio tracking (August 4). One male had moved upstream of the release site approximately 1.0 km, one male remained within approximately 0.25 km of the release site, and two males had moved downstream into the Yankee Fork Salmon River. No spawning-related observations were made in 1997 for this group of males. All four radio transmitters were recovered from the stream bottom or stream bank on August 15, 18, and 27.

Three days after the release of the four males in the East Fork Salmon River, two males were located approximately 5.0 km upstream of the release site. The other two males remained in the vicinity of the release site. After three weeks of tracking, the two upstream males continued to range in an upstream direction (approximately 10.0 km). The two remaining fish continued to hold at the release site. After four weeks of telemetry observations, the two upstream males had drifted back downstream to a location approximately 5.0 km upstream of the release site. Radio transmitters from the two males that held in the vicinity of the release site were recovered the last week of August and the first week of September. No movement was recorded for two of the males that had ranged upstream after the end of August. One of the upstream males drifted out of the East Fork Salmon River and was recovered at the Pahsimeroi Hatchery in September. No observations of spawning-related behavior were made for any male released to the East Fork Salmon River in 1997.

1998 In 1998, brood year 1994 and 1995 chinook salmon were released into the Lemhi River (34 BY94 females, 10 BY95 males), Bear Valley Creek (15 BY94 females, 9 BY95 males), and the West Fork of the Yankee Fork Salmon River (35 BY94 females, 9 BY95 males). No adults were released to the East Fork Salmon River.

In the Lemhi River 19 redds were identified in the stream area where the 44 captive chinook salmon ranged. Redds were construction in the release area from September 5 through September 27. During the evaluation period, several wild/natural chinook salmon were observed in the release interacting with captive-reared adults. While it is difficult to document the exact contribution hatchery-produced chinook salmon made in 1998, a greater number of redds were constructed than could have been attributed to the number of wild/natural chinook present. Seven captive-reared female chinook salmon carcasses were recovered. Three had failed to ovulate and spawn while the remaining four fish appeared to have partially spawned. Egg retention for these four females was estimated at approximately 50%.

An “off site” release was made in Bear Valley Creek, a Lemhi River tributary with high quality spawning gravel where wild/natural salmon are absent. Captive-reared chinook salmon with fresh and seawater histories were observed defending territory and constructing redds. Between September 8, and September 28 six redds were identified in the release area. No carcasses were recovered.

In the West Fork Yankee Fork Salmon River four redds were identified in the release area between September 3 and September 27. Wild/natural chinook salmon were observed in and above the study section but appeared to have completed spawning prior to the release of captive-reared adults. Five female carcasses were recovered, four appeared to have not ovulated and spawned while the fifth female appeared to have successfully spawned (<10% retained eggs; Hassemer et al. 1999).

1999. In 1999 brood year 1994, 1995, and 1996 chinook salmon from the Lemhi River were out planted to Bear Valley Creek (9 BY94 females, 24 BY95 females, 1 BY95 male, 16 BY96 males, and 12 BY97 males), and the East Fork Salmon River (6 BY94 females, 1 BY94 male). No adults were out planted in the West Fork Yankee Fork Salmon River in 1999.

Behavioral observations in Bear Valley Creek began following release (August 24) and continued through October 12, 1999. Thirty of the 33 female and seven of the 29 males released to the study section were observed exhibiting spawning behaviors. Agonistic behavior was observed on August 30 and test-digging on August 31. Redd construction was observed between September 10 and September 30. Thirty-one suspected redds were identified. In some cases, chinook salmon redds were superimposed on bull trout redds or on other chinook salmon redds. Several chinook salmon females were observed moving from one area of excavation to another. Some females were observed working gravel at four different locations. There were approximately 11 observations of bull trout and chinook salmon paired over the same redd. In many of these cases, spawning-related behavior between bull trout and chinook salmon were observed. Six male and 11 female carcasses were recovered. Nine female carcasses were examined for retained eggs. Five (56%) appeared to have spawned and deposited the majority of their eggs (the mean number of retained eggs for these five females was 17.2; range three to 30 eggs). One partially spawned female was recovered with 698 retained eggs and three females were recovered that appeared to have died before spawning (mean retained eggs = 1,536, range 1,175 to 1,933).

Behavioral observations began in the East Fork Salmon River immediately following release (August 25), and continued until September 24, 1999. On September 15, one of the six captive-reared females was observed in close proximity to a suspected redd. Her caudal fin was worn, but no male salmon were observed in the vicinity. Her carcass was recovered on September 24, and only ten retained eggs were found in her body cavity. The remaining five captive-reared females were not observed participating in spawning-related activity or observed near suspected redds. The single captive-reared male was observed on several occasions but never in close proximity to wild/natural or captive-reared females. Wild/natural chinook salmon were present in the study section.

2000 In 2000, only Lemhi River captive-reared adults chinook salmon were available for release. Maturing adults (1 BY94 female, 15 BY95 females, 32 BY96 females, 4 BY96 males, and 20 BY97 males) were released into Big Springs Creek, a tributary of the Lemhi River on July 11 and 12, approximately one month in advance of releases conducted in 1998 and 1999. No wild/natural chinook salmon were present in the Big Springs Creek study section.

Spawning activity in captive-reared fish occurred between September 16 and 23, 2000, while peak wild/natural spawning in the Lemhi River occurred between September 5 and 10, 2000. Captive-reared fish appeared to exhibit normal spawning behavior. Females aggressively defended redd sites from other females and non-chinook species. Male behavior was difficult to characterize due to the low number of males in the study section. The few males observed actively courted several females, and spawned multiple redds. An estimated 15 redds were constructed by captive-reared chinook in Big Springs Creek in 2000.

2001 In 2001, four, BY96 and 85 BY97 adults were released for natural spawning into the West Fork Yankee Fork Salmon River. Behavior and habitat association data were collected daily. Initially, fish were observed holding position or moving and were usually associated with pools or large woody debris. As the spawning season progressed, courting, and maintaining or holding on redds became their dominant activities. During this time, fish were associated with tailouts, although pools were used as resting and staging areas.

Eight captive-reared females were observed spawning: three with wild males and five with captive-reared males. Reproductive behavior was documented for at least 1-2 h prior to spawning and for 30 min post spawning. Male courtship (quivers and crossovers), female digging frequency and acts of aggression were counted. Observations showed that captive-reared males displayed the same courtship behaviors as wild males, but the frequency of behaviors differed between the two groups relative to the time until spawning. The frequency of quivers and crossovers by wild males generally increased as spawning approached with a pronounced spike immediately prior to spawning. Courtship frequencies by captive-reared males remained constant or declined slightly during the period leading up to spawning, although the spike immediately prior to spawning was observed. The largest difference between the two groups of males was that captive-reared males were much less aggressive toward other chinook salmon or resident fish than were wild males.

Captive-reared females made nest digs approximately every 2-3 min until egg deposition, then females proceeded to cover dig almost continuously for about 10 min, and maintained elevated digging frequencies for at least 30 min. These are behavior patterns similar to those reported in the literature.

In previous years, captive-reared chinook salmon spawned several weeks later than wild fish in the same or nearby streams. Consequently holding maturing adults on chilled water was used to attempt to advance spawning. Field observations of spawning dates for the two groups of females in the West Fork Yankee Fork Salmon River did not appear to differ. However, all chilled-treatment females except one spawned by September 5, 2001, while ambient-control females continued to initiate spawning until September 17, 2001. Experimental water temperature manipulations during final maturation in fresh water to advance the spawn timing of captive-reared fish produced mixed results. The effects of chilled water on spawn timing remain unclear.

In October eggs were collected from a portion of the redds dug by captive-reared chinook salmon to estimate egg fertilization and survival rate to the eyed stage of development. Eggs were collected from five of the eight redds sampled. Live eggs ranged from 0% - 89%. One redd contained no live eggs although it appeared to have been constructed in extremely high quality habitat. Sampling revealed this redd was constructed in thin (approximately 7 cm) gravel/cobble armoring over a large, decayed log.

<u>2002</u> In 2002, maturing adults were released on August 6 and 7 in the EFSR and, August 8, 2002 in the WFYF. The EFSR received 0, 46, 45, and 40 maturing BY97, BY98, BY99, and BY00 adults. The WFYF received 27, 57, 76, and 56 maturing BY97, BY98, BY99, and BY00 adults. Adults released to the EFSR had access to the entire length of the river, while those released in the WFYF were confined to the area above a weir. Trap boxes built into the structure allowed wild chinook salmon and resident species to be passed in either direction. However, study fish attempting to move downstream were returned to the stream above the weir.

In 2002 spawning behavior and timing in the WFYF, the effect of chilled water on maturation timing in these fish and those from the LEM (spawned at Eagle Hatchery), and movement rates and magnitudes of fish released into the EFSR was investigated.

Two criteria were used to evaluate spawning by captive-reared females. The first was the percentage of females from each temperature treatment that initiated redds and the second was the percentage that initiated redds of those that were known to have survived to the date the first female from their treatment group initiated spawning. For brood year 1997 females, 66.7% of females from the chilled water (treatment) group initiated redds compared to only 23.1% of those from the ambient temperature (control) group. Chilled treatment females from this brood year also had higher survival to the first date of spawning for their group (75.0% vs. 46.2%) and higher spawning participation (88.9% vs. 50.0%) from the surviving individuals. Similar results were observed in brood year 1998 females, with 80.0% of those from the chilled treatment constructing redds compared to only 21.4% of the ambient control fish. Furthermore, 92.3% of chilled treatment fish that survived to the spawning period spawned, but only 33.3% of the surviving control fish constructed redds. A small number of fish from this brood year transferred to Eagle after the main group, referred to as "late arrivals", were not included in the temperature experiment, but were released to spawn with the experimental fish and spawned at rates similar to fish reared on chilled water. In conclusion, the experimental water temperature manipulations to advance spawn timing in captive-reared fish produced mixed results again this year. Males held on chilled water in the hatchery matured earlier than females, but no difference in maturation timing was observed under field conditions for either sex. However, females from the chilled group had greater survival and spawned more redds than those held on ambient temperatures.

Spawning by eight captive-reared females: one with a wild male and seven with captive-reared males was observed and documented for at least 1-2 h prior to spawning and for 30 minutes post spawning. Male courtship (quivers and crossovers), female digging frequency, and aggression by either sex was quantified.

Captive-reared males displayed the same courtship behaviors as wild males, but because spawning involving a wild male was only observed in one event this year, comparisons between the two groups can only be made with last year's observations and values reported elsewhere in the literature. Crossover and quiver frequencies in captive-reared males remained constant or increased slightly as spawning neared. Additionally, these rates were similar to those observed in captive-reared fish in 2001. The frequency of quivers and crossovers by the wild male in 2002 was much lower than observed in wild males in 2001. Another difference between observations in the two years is that in 2001 the frequency of male aggression in captive-reared fish was much less than observed in wild males, but this difference was not as apparent in 2002. Aggression in captive-reared males was similar to that of the one wild male observed spawning in 2002 and only slightly less than average rates documented in 2001 for wild males.

Captive-reared females displayed digging patterns similar to those reported elsewhere in the literature. Females made nest digs approximately every 2-3 minutes until egg deposition, then females proceeded to cover dig almost continuously for about 10 minutes, and maintained elevated digging frequencies for at least 30 minutes.

On the East Fork of the Salmon River, fish movements were monitored using radio telemetry. After release most salmon moved downstream. Several females did however, move upstream immediately after release. Subsequent tracking showed minimal movements by the majority of individuals of both sexes. A few individuals did show measurable movement, but these events were limited and preceded by prolonged periods of holding.

On October 8 - 9, 2002, eggs were collected from a portion of the redds dug by captive-reared chinook salmon in the WFYF to estimate fertilization rates and estimate the number of juveniles that could be expected to be produced from program fish. Eggs were collected from 17 of the 18 redds sampled, and nine redds contained fertilized eggs. Based on the number of redds known to be constructed by captive-reared females (n = 33) and fecundity estimates from spawning at Eagle, as many as 14,500 fertilized eggs were contributed to the WFYF in 2002 by captive-reared fish.

Uncertainties and Limitations of Releasing Captive-reared Adults

Several limitations associated with the reintroduced captive-reared chinook salmon have been identified:

1. the limited availability of age 4 and age 5 captive-reared males,
2. asynchronous spawn timing for captive-reared and wild/natural chinook salmon, and incomplete or arrested maturation and ovulation in captive-reared females,
3. questionable gamete quality
4. insufficient physical ability of captive-reared adults to negotiate natural stream conditions, construct successful redds, and compete with other species for spawning privileges.

In culture, maturation of males at age 2 and age 3 exceeds that of their wild/natural counterparts. To help offset the precocial development of male fish, water temperature and diet are being manipulated. Juvenile fish are reared in chilled water at the IDFG Eagle Fish Hatchery, ambient water temperature (13.5°C) is reduced to between 8.0°C and 10.0°C. Feeding regimes have also been developed to adjust ration seasonally to mimic natural conditions. In addition, it is hoped that hydraulic egg collection provides equal sex ratios. Parr collected from target streams between 1995 and 1998 were predominantly female (65%).

Asynchronous spawn timing has been observed since the inception of the adult out planting program in 1998. In 2001, NMFS Northwest Fisheries Science Center researchers collaborated with IDFG to study maturation physiology and the development of additional chilled water capacity at the IDFG Eagle Fish Hatchery. The physiological element, now identified in Project 199305600, is underway and designed to compare the progress of maturation as well as to evaluate the bioenergetics of migration in ocean-reared hatchery fish. It is hoped that this research will provide some insight as to when the dysfunction in captive-reared adults is occurring and how to correct it.

Physical performance deficiencies in captive-reared adult, chinook salmon appear to exist. Based on observations during spawning, captive-reared adults are less robust physically than their wild/natural counterparts. As a result, the selection of appropriate spawning habitat could be compromised as fish "settle" for locations that suit their physical limitations. Associated with this suspected dysfunction is the potential for adults to build shallow or poorly armored redds that place deposited eggs in jeopardy of being "scoured out". To verify whether or not captive-reared adults are depositing eggs, eyed-eggs were recovered from the 15 redds constructed in Big Springs Creek in 2000. Eggs were successfully deposited in 13 of the 15 redds. However, only 21% of the 440 eggs recovered were viable. A large percentage of eggs from several redds were found to be unfertilized. A number of eggs in the Big Springs Creek sample had apparently died after developing to the eyed stage. Smothering by fine sediments is the most likely cause of this mortality. Habitat selected by fish for spawning appeared to have unacceptable levels of sand and silt (>20% estimated). Nevertheless, egg survival results were less than optimal in 2000. Whether this is completely an environmental phenomenon or related to physiological dysfunction, is not clear. In addition, findings from ongoing NMFS research addressing the effect of forced exercise regimes on the reproductive success of captive-reared chinook salmon (Project No. 199105500) will hopefully provide insight as to whether physical deficiencies are limiting reproductive success in the habitat.

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