Tucannon River Spring Chinook Salmon Captive Broodstock Program

Final Project Completion Report

October 1, 1999 – September 30, 2009

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Abstract

This report summarizes the objectives and accomplishments of the Tucannon River Spring Chinook Salmon Captive Broodstock Program. The WDFW initiated a captive program in 1997. The captive program collected sac fry from the hatchery supplementation program from five (1997-2001) brood years (BY) with additional sac fry collected from the 2002 BY in order to have extra captive males on hand to spawn. The overall goal of the Tucannon River captive program was for the short-term rebuilding of the Tucannon River spring Chinook salmon population, with the hope that natural production would sustain the population in the future. The project goal was to rear captive salmon selected from the supplementation program to adults, spawn them, rear their progeny, and release approximately 150,000 smolts annually into the Tucannon River between 2003-2007. This was expected to provide a return of about 300 adult fish to the Tucannon River of captive origin per year between 2005-2010. These smolts, in combination with the current conventional hatchery supplementation program and natural production, were expected to produce 600-700 returning adult spring Chinook to the Tucannon River each year from 2005-2010.

Selecting fry from parents based on Bacterial Kidney Disease (BKD) screening appeared to have benefited the program, as BKD was not an issue with the Tucannon captive broodstock as it has been with other Chinook salmon captive brood programs. Overall survival and health of captive brood adults was good throughout the duration of the program.

Adult spawners from the captive program were significantly smaller than conventional hatchery and natural origin fish. The captive broodstock produced significantly larger eggs, but egg quality was poor, with high egg mortality. The large eggs in small adults resulted in significantly lower fecundity, relative fecundity, and reproductive mass in captive females compared to conventional hatchery and natural origin females of the same age.

During 2002, adult captive broodstock determined to be in excess of broodstock needs were outplanted into the upper Tucannon River in order to stay within the approved release goal of 150,000 smolts. Due to the low frequency of natural spawning by released fish, high mortality due to evidence suggesting predation and illegal harvest, and high egg mortality in the hatchery during 2002, the priority for excess fish in the future was changed. The co-managers agreed to spawn excess adults, and release their progeny as parr.

The captive program did provide additional smolts for release that otherwise would not have occurred had the program not been in place. Downstream survival rates of smolts based on PIT tagging revealed that survival tended to be higher every year for conventional hatchery fish compared to captive progeny. However, with the exception of the 2006 brood year, differences were not significant.

As anticipated, due to their protection in the hatchery environment, egg-to-parr, parr-to-smolt, and egg-to-smolt survivals of captive progeny and conventional hatchery fish were higher than natural origin fish. However, egg-to-parr and egg-to-smolt survivals were higher for conventional hatchery fish than captive progeny. Smolt-to-adult return (SAR) survival has effectively been < 0.02% for the first five years of the captive program compared to SARs of

0.13% and 1.07% for conventional hatchery and natural origin fish, respectively. Captive progeny size at release was increased from 30 g/fish to 50 g/fish for the 2005 and 2006 brood years. We are cautiously optimistic this change will increase SAR survival.

Based on adult returns from the 2000-2005 brood years, captive program produced only 0.17 adults for every spawner which is considerably lower than naturally reared salmon that produced 0.67 adults for every spawner. Conventional hatchery reared fish produced 1.66 adults per spawner and was usually the only group to return adults above replacement levels. It is unknown whether hatchery domestication effects or other unknown factors have played a role in the poor returns, as the captive progeny and conventional hatchery fish are reared and released in the same manner. Based on the results to date, the Tucannon River spring Chinook captive broodstock program has been unsuccessful in achieving its adult return goals.

The WDFW LSRCP evaluation program will continue to document returning adults from the captive program and compare their survival to survivals from the conventional hatchery supplementation program and natural origin fish. A final assessment of the captive program will be submitted for publication in a peer-reviewed journal after the final adults return in 2011.

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Introduction

Reporting Period

This report summarizes the major accomplishments of the Tucannon River spring Chinook[1] salmon (*Oncorhynchus tshawytscha*) captive broodstock[2] program from 1 October 1999 to 30 September 2009 (FY2000 – FY2009). This report, while originally intended to cover activities accomplished exclusively under the BPA funded program, includes activities funded by the U.S. Fish and Wildlife Service Lower Snake River Compensation Plan (LSRCP) program as well for comparative purposes. This was done to provide readers with a complete timeline of the activities that have occurred over the course of the program and compare the captive program to the conventional hatchery supplementation program and natural origin fish during the same time period. The genetic (microsatellite DNA) analysis for this program will be covered in a separate report. For detailed information on individual brood years the reader is directed to the annual reports located on the BPA website. Although this is the final report to be submitted to BPA, the last captive progeny adults are expected to return to the Tucannon River in 2011. Continued yearly assessments will occur under LSRCP funding. A final assessment of the captive program will be submitted for publication in a peer-reviewed journal after the final adults return in 2011.

Tucannon River Spring Chinook Program Overview

Prior to 1985, artificial production of Chinook in the Tucannon River was limited to only two fry releases in the 1960s (WDFW et al. 1999). The Washington Department of Fisheries released 16,000 Klickitat (2.3 g fish or 197 fish/lb) and 10,500 Willamette (2.6 g fish or 175 fish/lb) stock Chinook into the Tucannon River in August 1962 and June 1964, respectively. The out-planting program was discontinued after a major flood destroyed the rearing ponds in 1965. Neither of these releases is believed to have returned any significant number of adults. After completion of the four lower Snake River dams, the LSRCP program was created to provide hatchery compensation for the loss of spring and fall Chinook salmon, and summer steelhead (*O. mykiss*) in the Snake River resulting from construction and operation of the four lower Snake River power dams (USACE 1975). In 1985, Washington Department of Fish and Wildlife (WDFW) began the hatchery Chinook production program in the Tucannon River by trapping wild (unmarked) adults for the hatchery broodstock. Hatchery-origin fish have been returning to the Tucannon River since 1988. The hatchery broodstock since 1989 has consisted of natural and hatchery-origin fish.

In 1992, the National Marine Fisheries Service (NMFS) listed Snake River spring/summer Chinook salmon as "endangered" (April 22, 1992 Federal Register, Vol. 57, No. 78, p 14653), which included the Tucannon River stock. The listing status was changed to "threatened" in 1995 (April 17, 1995 Federal Register, Vol 60, No 73, p 19342). From 1993 to early 1998, WDFW operated the hatchery supplementation program under Section 10 direct take permit

[1] From this point forward, the term "Chinook" refers to spring Chinook salmon unless otherwise noted.
[2] From this point forward, the term "captive" refers to any fish that was associated with the captive program at Lyons Ferry Hatchery.

#848 for artificial propagation and research. From late 1998 to 2003, WDFW operated both the supplementation and captive program under Section 10 direct take permits #1126 (artificial propagation), and #1129 (research), and since 2003 the program has operated under the Tucannon River Spring Chinook Hatchery and Genetic Management Plan.

The Endangered Species Act (ESA) allows for "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures pursuant to the Act are no longer necessary" (ESA 1973). Consistent with that provision, WDFW and the co-managers [The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Nez Perce Tribe (NPT)] decided in 1997 to implement the Tucannon River captive program to sustain and potentially recover this listed population. Both of the hatchery programs (conventional supplementation and captive) are being conducted with the recognition that artificial propagation may have potentially deleterious direct and indirect effects on the listed fish (Hard et al. 1992; Cuenco et al. 1993; Busack and Currens 1995; Campton 1995). These effects may include genetic and ecological hazards that cause maladaptive genetic, physiological, or behavioral changes in donor or target populations, with attendant losses in natural productivity (Hard et al. 1992). Araki et al. (2007) found that even a few generations of domestication may have negative effects on natural reproduction of fish in the wild. Because the effects of a captive brood program expose the population to artificial selection for a longer part of the life history, its effects may be exacerbated, compared to a conventional supplementation hatchery program. However, WDFW and the co-managers believed the risk of extinction in the Tucannon River was high enough to warrant a short-term, limited intervention in addition to the supplementation program. This program was pre-defined to last for only one-generation cycle (five brood years), to minimize potential negative effects due to the short-term nature of the program.

Annual adult returns between 1985-1993 were estimated to be 400-750 natural and hatchery-origin fish combined (Figure 1). In 1994, the adult escapement declined severely to less than 150 fish, and the run in 1995 was estimated at 54 fish. In 1995, WDFW started the captive program, but discontinued it based upon higher returns predicted for 1996 and 1997. Unfortunately, the 1996 and 1997 returns were not as strong as predicted. In addition, major floods in 1996 and 1997 on the Tucannon River was presumed to have destroyed most of the natural production for both brood years. Moreover, an 80% loss of the hatchery egg take occurred in 1997 due to a malfunction of a water chiller that cold shocked the eggs. Because of the lower returns, and losses to both natural and hatchery production, the Tucannon River spring Chinook captive program was re-initiated with the 1997 brood year.

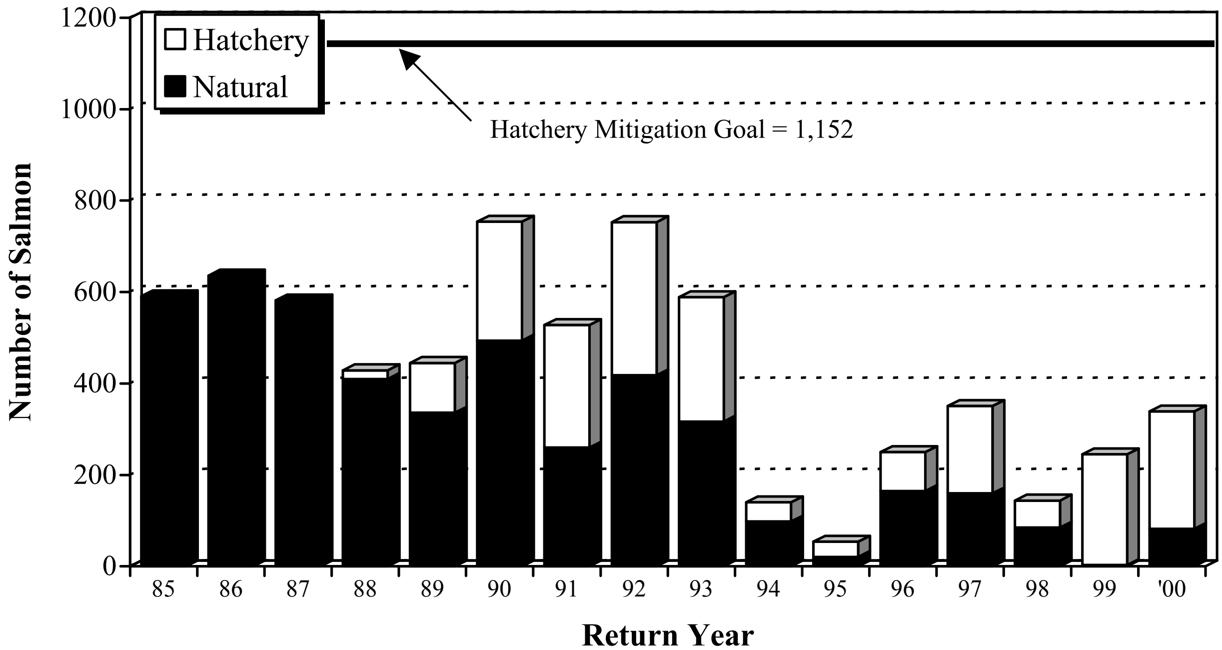

Figure 1. Total estimated escapement of Tucannon River spring Chinook salmon from 1985-2000.

Key to the Tucannon River Chinook restoration effort will be whether or not the natural population can consistently return above the replacement level. Since 1985, WDFW has monitored and estimated the performance of the natural population for comparison to the conventional hatchery program as part of the LSRCP program (USFWS 1998). Monitoring efforts to date have shown the natural population below replacement almost every year (Figure 2). Unless the natural population returns to a point above replacement, the overall goal of the Tucannon River Chinook restoration program will not be met.

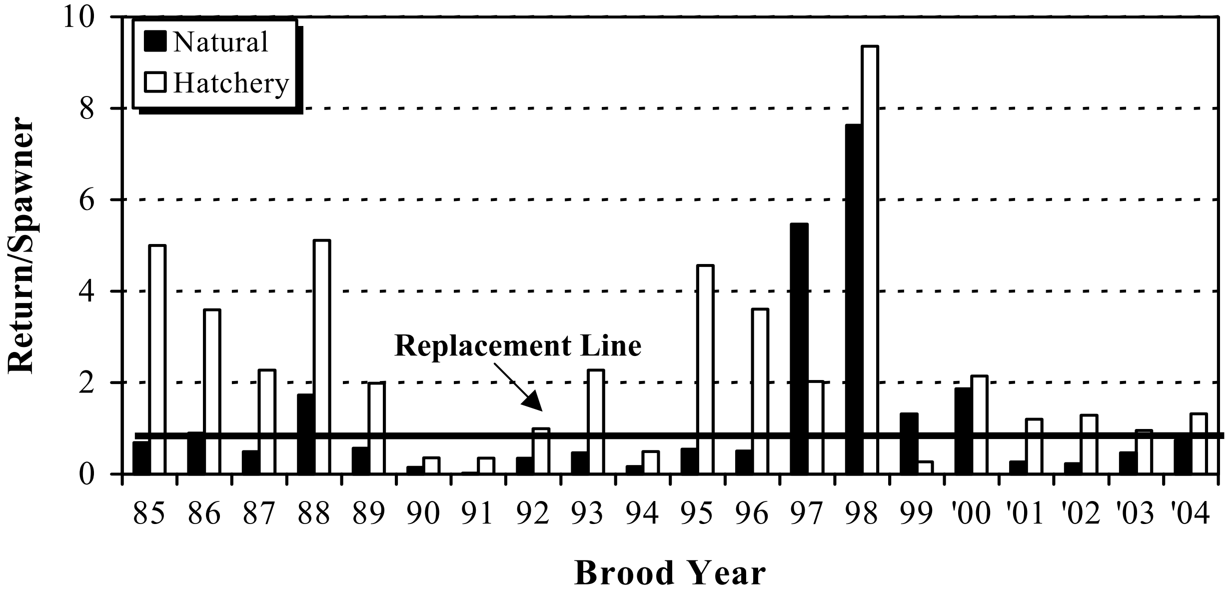

Figure 2. Return per spawner (with replacement line) for Tucannon River spring Chinook salmon for the 1985-2004 brood years (2004 brood year incomplete).

Tucannon River Watershed Characteristics

The Tucannon River is a third order stream that empties into the Snake River between Little Goose and Lower Monumental dams approximately 622 river kilometers (rkm) from the mouth of the Columbia River (Figure 3). Stream elevation rises from 150 m at the mouth to 1,640 m at the headwater (Bugert et al. 1990). Total watershed area is about 1,295 km^2. Mean discharge is 4.9-m^3/sec with a mean low of 1.7-m^3/sec (August) and a mean high flow of 8.8-m^3/sec (April/May). Chinook typically spawn and rear above Tucannon rkm 40. WDFW and the co-managers believe producing smolts will maximize recovery efforts from the captive and conventional hatchery programs, and acclimated releases in the upper watershed have the best chance for high survival and return to the best spawning and rearing habitat.

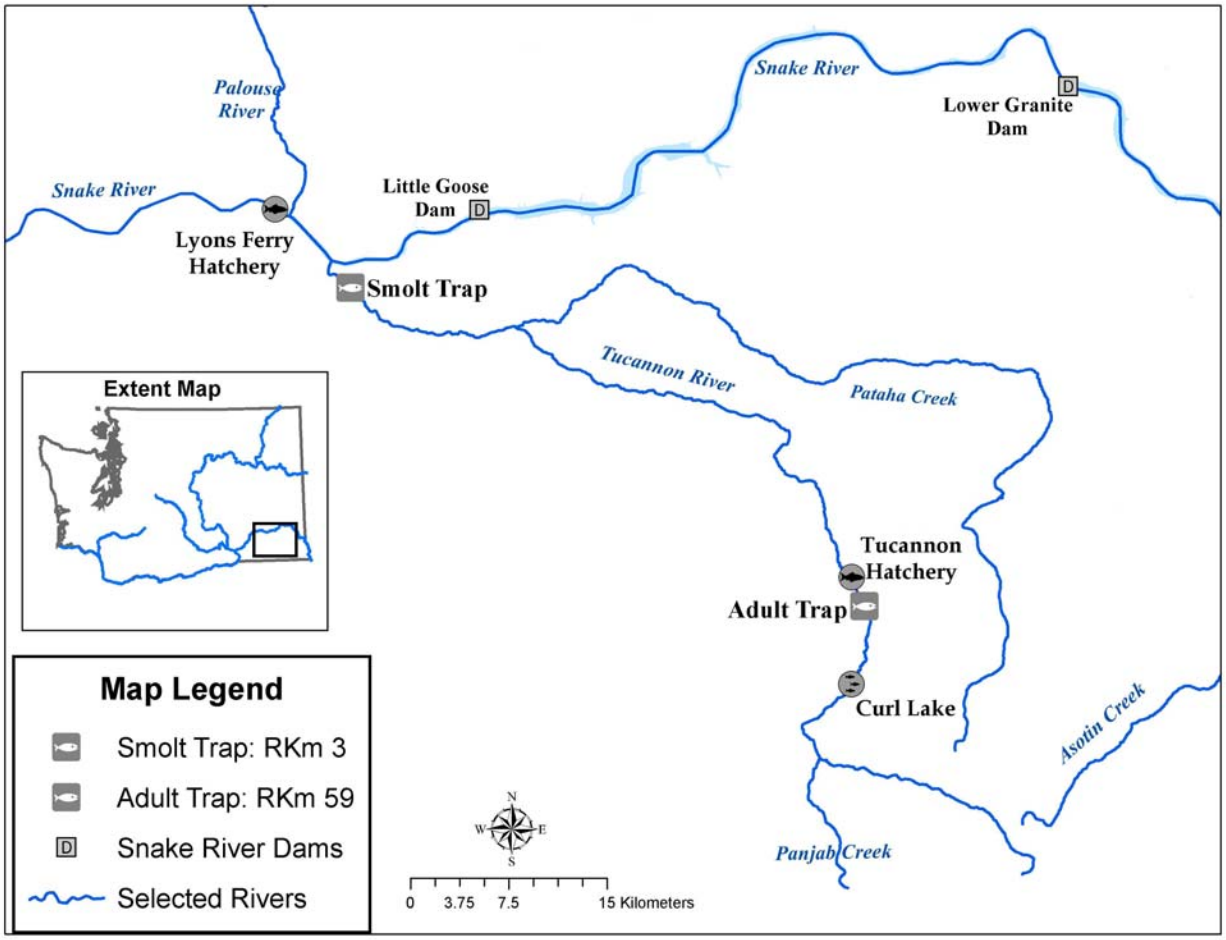

Figure 3. Location of the Tucannon River Basin, a tributary of the Snake River, and locations of Lyons Ferry Hatchery, Tucannon Hatchery, and Curl Lake Acclimation Pond.

It is hoped that initiatives for habitat improvement within the Tucannon Basin (BPA funded Tucannon River Model Watershed Program and Subbasin Plan, and the State of Washington Governor's Salmon Recovery Plan) that are aimed at increasing in-river survival, improved ocean conditions, and continued adult and juvenile passage improvements at Federal Columbia River Power System (FCRPS) dams, will be enough to return the natural population productivity to above the replacement level. For example, broad based goals of the Tucannon Model Watershed Program are to: 1) restore and maintain natural stream stability, 2) reduce water temperatures, 3) reduce upland erosion and sediment delivery rates, 4) improve and re-establish riparian vegetation, and 5) increase amounts of large woody debris. Managers hope that these habitat recovery efforts will ultimately increase survival of naturally reared Chinook in the river. While this will only provide an increase to juvenile population numbers (parr or smolts), greater numbers of smolts should return more adult fish to the Tucannon River even if passage problems and ocean conditions remain unchanged. The captive program was intended to provide a quick increase in the number of adults that will produce progeny to take advantage of improved habitat.

Facility Descriptions

The program utilizes three different WDFW facilities: Lyons Ferry Hatchery (LFH), Tucannon Fish Hatchery (TFH), and Curl Lake Acclimation Pond (AP). Lyons Ferry Hatchery is located on the Snake River (rkm 90) at its confluence with the Palouse River (Figure 3). LFH was constructed with funds provided by the U. S. Army Corps of Engineers, and has subsequently been funded through the LSRCP program of the U.S. Fish and Wildlife Service, contracted as a direct cost by BPA. The LFH is used for adult broodstock holding and spawning, and incubation and early life stage rearing until production marking. Fifteen 1.2-m diameter circular starter tanks were purchased when the captive program was started in 1995. In 1999, LSRCP purchased and supplied the funding for installation of eight 6.1-m diameter circular rearing tanks for the adults, and for relocation of the small circular tanks. The tanks were installed during August and September of 1999 in the captive rearing area at LFH. During 2000, BPA supplied funding for security fencing around the broodstock rearing area.

The TFH, located at rkm 59 on the Tucannon River (Figure 3), has an adult collection trap on-site. Following marking at LFH, juveniles are transferred to TFH to rear through winter. In mid-February, the fish are transferred to Curl Lake AP for a minimum of four weeks of acclimation. Curl Lake AP is a 0.85 ha natural bottom lake with a mean depth of 2.8 meters (pond volume estimated at 22,203 m^3). Sometime between the middle of March and the beginning of April, the pond exit is opened and the fish are allowed to volitionally emigrate from the lake until the third week of April when they are forced out.

Goal

The captive goal was to collect 290,000 eggs/year from captive females when three complete age classes (ages 3 to 5) were spawned concurrently. Under the original program design, these eggs were expected to produce about 150,000 smolts for release from Curl Lake AP. Depending on smolts produced each year this should provide a return of about 300 adult fish of captive origin per year from 2005 to 2010 if a survival rate of 0.2% to the weir was achieved. These fish combined with fish from the conventional hatchery program and natural production from the river were expected to return 600-700 fish annually between 2005-2010. While this is still well below the LSRCP mitigation goal, it would return the in-river population level to a pre-1994 level. As described in the Tucannon Master Plan, measures have been taken to minimize and mitigate potential genetic and/or ecological hazards of this program to the listed population (WDFW et al. 1999).

Source of Captive Brood Population

The captive population was selected from sac fry produced from the conventional hatchery program during the 1997-2001 BYs (WDFW et al. 1999). Because males mature at an earlier age than females, additional sac fry were collected from the 2002 BY to have a sufficient number of males available at the end of the program to cross with captive females. The conventional hatchery broodstock consist of both natural and hatchery returns (generally 1:1 ratio). Returning hatchery fish used in the conventional hatchery broodstock are verified to have come from the

Tucannon River stock through CWT verification. Collection of eggs/fry from the conventional hatchery program was done to lessen the effects of removing more fish from the natural population. Also, disease history and origin of parents would be known, and the overall effect to the conventional hatchery program would be minimal.

During the spawning process in the conventional hatchery program, the eggs of two females were split in half with each lot fertilized by a different primary male (each male also acts as a secondary male). Due to the relatively small population size, a 2 x 2 factorial mating (Figure 4) strategy has been incorporated into the conventional hatchery program to increase effective population size and maintain genetic diversity (Busack and Knudsen 2007). Milt from a secondary male was added as a backup after 30 seconds. Actual fertilization takes place in a few seconds, so the backup male is not likely to contribute substantially to each individual egg lot unless semen from the primary male is non-viable.

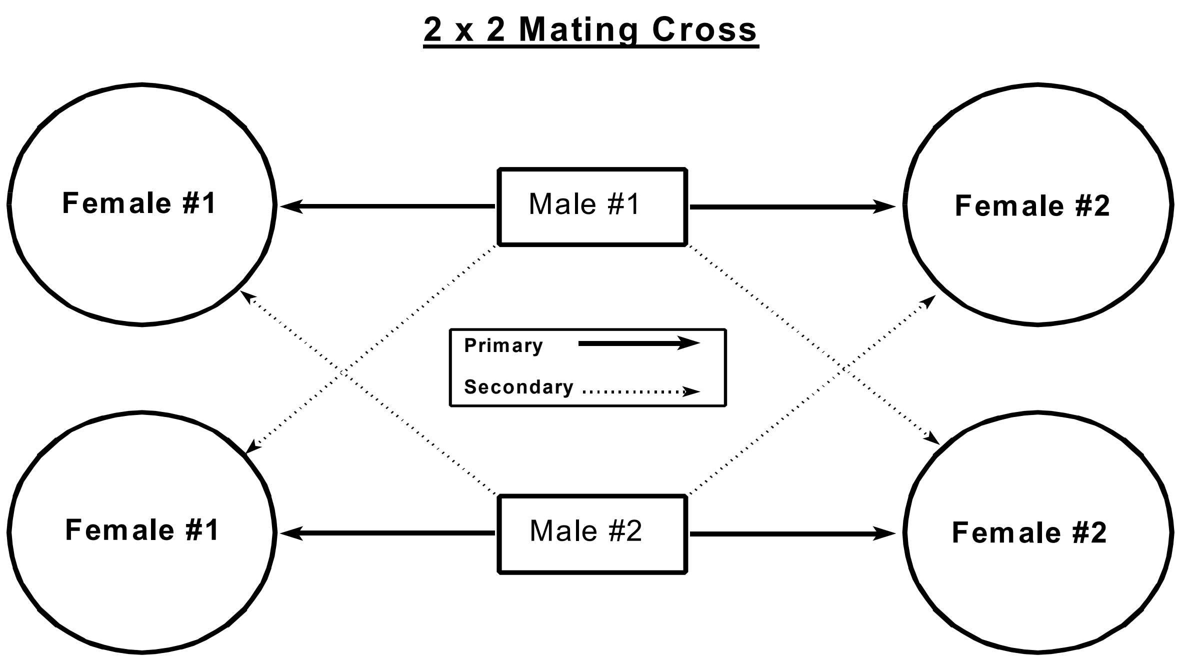

Figure 4. Diagram of the 2 x 2 mating scheme used by WDFW in the conventional hatchery and captive program. All progeny in this diagram are defined as a family group.

Because of the mating strategy, some progeny from the two females are likely related as a family unit. Therefore, we consider all crosses with identical males (whether as primary or secondary to the mating) as one family unit to avoid within-family matings in the future. So while only 15 "family" units were chosen for the program, actual contribution of male and female parents (population size) to the captive program on a yearly basis has been higher. The actual number of parents that comprise the 1997-2002 BYs are given in Appendix A. Effective population size (N_e) for each brood year was calculated by the formula:

$$N_e = 4 (N_M)(N_F)/(N_M + N_F)$$

Where: N_M = number of males
N_F = number of females

The effective population sizes of the 1997-2002 BYs were 53, 58, 42, 56, 58, and 59, respectively. Allendorf and Ryman (1987) and Verspoor (1988) have suggested that little (<1%) genetic variability will be lost in most salmonid species if the N_e of the founding population is greater than 50.

Selection of fry for the captive brood program was based on Bacterial Kidney Disease (BKD) screening of females, parent origin, and crosses (Appendix A). Screening for BKD, which is caused by the bacterium *Renibacterium salmonirum*, was a major factor in WDFW's decision to collect fry from the conventional hatchery program. By having the test results prior to selection, and by having rearing criteria that called for minimal sampling/handling, we felt that BKD outbreaks would be minimized. Spawned females were examined for BKD using the Enzyme Linked Immunosorbent Assay (ELISA) technique. Only females that were categorized as "Low" (0.11 - 0.19 Optical Density (OD)) or "Below Low" (< 0.11 OD) ELISA result were selected, with priority given to "Below Low" females. Priority for selection (in the following order) of fry was given to Natural x Natural, Natural x Hatchery (Mixed), and Hatchery x Hatchery crosses. All BYs identified for the program followed the same criteria.

Eighty fish from each of the 15 "family units" were selected (1,200 total fish) from each BY and each family group was moved to an individual 1.2-m circular fiberglass tanks. After rearing for one year, each of the "family" groups was reduced to 30 fish/family (450 fish/BY) by random selection just prior to tagging. Excess fish were returned to the conventional hatchery production group. Fish destined for the captive program were tagged by "family" group with a CWT in the snout and adipose fin (backup). This was to verify "family" groups during future spawning activities so that full or half-siblings were not mated together. In addition to the CWT, an alphanumeric visual implant (VI) tag was placed behind the left or right eye to identify each fish. The VI tag, when it was retained, provided a quicker external "family" identification method than the CWT. In addition, fish that retained the VI would provide individual growth rates. After the fish were tagged, they were transferred to one of the 6.1-m circular fiberglass tanks for rearing to maturity. Once the fish were transferred to the larger rearing tanks, they were not moved again unless survival rates were greater than anticipated, or density limits were exceeded within the rearing tanks. At maturity, fish were transferred to the adult raceway located in the spawning building. Family size and tagging procedures were the same for all brood years collected.

Density limits for each rearing tank were established prior to any stocking of fish. Most of the density limits prescribed were taken from the WDFW Dungeness River Captive Broodstock Program, where similar size starter and adult rearing tanks were used. Based on those density limits and expected survival and maturation rates, we were able to design the facilities needed. The current fish number maximums are as follows: 1.2-m circular tanks = no more than 200 fish/tank at age-1; 6.1-m circular tanks = no more than 150 fish/tank at age-3, or 100 fish/tank at age-4. Fish from each captive year were kept for a maximum of five years. If the fish did not spawn after that time it was killed outright and removed from the captive population.

Fry from each brood year were collected as described above, with appropriate families chosen for the program (Appendix A). Data on average length (mm), weight (g), and condition factor (K) for each "family" group were compiled during tagging (Appendix B).

Hatchery Rearing and Spawning

Captive Broodstock Rearing

Captive fish were reared at LFH using standard fish culture practices and approved theraputants in pathogen free well water that is a constant 11ºC. Each 6.1-m circular captive tank was supplied with about 581 L/min water flow, while the 1.2-m tanks received about 23 L/min. To reduce the risk of catastrophic fish loss due to hatchery facility or operational failure, a number of safeguards were in place. LFH is staffed full time by personnel living on-station, providing for the protection of fish from vandalism and predation. The hatchery is also equipped with back-up generators in the event of power outages. All staff are trained in proper fish handling, transport, rearing, biological sampling, and WDFW fish health maintenance procedures to minimize the risk of fish loss due to human error. All fish were handled, transported, and propagated in accordance with the WDFW Fish Health Manual (WDFW 1996) and Pacific Northwest Fish Health Protection Committee (PNFHPC 1989) disease prevention and control standards to minimize loss due to disease. Sanitation procedures were employed to reduce the transfer and incidence of fish diseases, and to promote quality fish in accordance with PNFHPC (1989) and Integrated Hatcheries Operations Team (Peck 1993) guidelines.

A variety of high quality commercial feed was provided through a state contract, and feed size varied with the estimated fish size of the different BYs. We have used Moore-Clark Nutra, Moore-Clark Fry, Bio-Products Salmon Brood Feed, and Moore-Clark Pedigree Trout Brood Feed on the captives. Estimated size only was generally used to prescribe feeding rates, as WDFW decided initially that too much handling of the fish to determine growth and size would jeopardize fish health. This decision resulted from problems that Oregon Department of Fish and Wildlife (ODFW) and Idaho Department of Fish and Game (IDFG) captive programs experienced during their first years of operation with monthly fish sampling. Due to the degree of early maturation of females in the 1997 and 1998 brood years, size-at-age recommendations were revised to produce more mature age-4 and 5 fish. Size-at-age goals were: age-1, 20-25 g; age-2, 150-200 g; age-3, 900 g; and age-4, 4,000 g. Daily satiation feeding was incorporated to obtain a larger size of adults at maturation. All captive fish were reared outside under natural photoperiod conditions. However, each of the 6.1-m circular tanks was covered with camouflage netting to provide shade and lessen stress on the adults. The netting also prevented fish from jumping out of the tank. The ponds were cleaned weekly by lowering the water column and brooming the sides and bottom of the tanks.

During late June to early July, captive fish that were age-2 or greater were examined for signs of sexual maturation. Maturation was determined by a darkening in body coloration, as other morphological sexual characteristics were not as obvious. Mature female captives were injected with Erythromycin (20 mg per kg of body weight) at sorting to prevent Bacterial Kidney Disease. The broodstock were also treated with a formalin flush (167 ppm) every other day to control fungus (*Saprolegnia* sp.). Mature captives were transported to broodstock holding raceways in common with, but separated by screens from broodstock (hatchery and natural-origin) collected from the Tucannon River. Immature fish not transported to the spawning building were also treated with formalin for two weeks after handling to prevent a fungus outbreak.

Captive Broodstock Spawning

Fish were anesthetized with MS-222 (tricaine methanesulfonate) and examined weekly for ripeness during the spawning season (late August to early October). Ripe females were killed and the eggs excised and collected into numbered plastic buckets. Milt from males was collected into numbered plastic bags, oxygenated, and stored on an insulated layer of ice until used for fertilization.

Using the same spawning matrix as described earlier (Figure 4), the eggs of two females were split in half and fertilized by two males following a 2 x 2 factorial spawning matrix approach. Milt from a secondary male was added as backup after 30 seconds to help ensure maximum fertilization. Mature fish (primarily age-2 jacks) not used for spawning were sacrificed at the end of the spawning season. Unlike other captive brood programs (e.g., Oregon Grande Ronde), cryopreservation of milt has not been employed as part of the program because obtaining enough males to spawn with mature females was never a problem.

Data collected from spawned fish included VIE identification number or CWT, fork length, postorbital to hypural-plate (POH) length, weight (from 2001 on), and tissue samples for DNA analysis.

The fertilized eggs were recombined and placed into iso-buckets, one female per bucket, and disinfected in an iodophore bath at the standard rate of 100 ppm for one hour. At the end of disinfection the water was turned on to 1.94 L/minute for each bucket. The eggs were treated every other day with formalin at 1,667 ppm (37% formaldehyde) for 15 minutes for fungus control. Eggs were left untouched until they reached the eyed egg stage (approximately 580-600 temperature units (TUs)). At this time eggs were shocked and the following day the dead eggs were removed and enumerated. A sample of 100 live eggs was weighed and then all eggs were weighed with the mean weight per egg (egg size) applied to derive total number of live eggs. This estimate was decreased by 4% to compensate for water adherence to the eggs (WDFW Snake River Lab, unpublished data). The live and dead egg totals were combined to estimate total fecundity. The live eggs were moved into the vertical incubators for development and hatching. Water flow in the vertical tray incubators was set at 13.56 L/minute. When the alevins had fully absorbed their yolk they were moved to outside raceways (3 m x 27 m x 1.1 m) at LFH for rearing.

Captive Broodstock Progeny Rearing

Lyons Ferry Hatchery

The fry were ponded and fed Bio-Diet Starter #3, 6-8 times per day, seven days a week for the first two weeks. When fish were approximately 0.91 g they were treated with Erythromycin medicated feed for 28 days for the prevention of BKD. The feed was eventually changed to Bio-Diet Grower increasing from 1.0 mm to 2.5 mm according to the size of the fish.

Once they were feeding actively the protocol was to feed to satiation daily until they reached 1.5-2.3 g/fish. The feeding rates and number of days fed was then reduced so that growth would be according to program requirements. To maintain a healthy environment, fish losses were removed and the screens broomed daily. The pond bottoms were vacuumed weekly.

In September, at approximately 13 g/fish, all captive progeny smolts were marked differently from conventional hatchery progeny for identification upon adult return. Captive smolts were unclipped and tagged with an agency-only wire tag (2000-2002 BYs) or CWT in the snout (production fish have an elastomer tag and CWT). When conventional hatchery or captive fish return as adults at the TFH adult trap, each unmarked (no adipose clip) adult Chinook will be scanned for wire in the snout and examined for a VIE tag. If the fish is not adipose fin clipped, and wire is present in the snout and no VIE is present, the fish is likely from the captive program. After tagging, the fish were held for at least two weeks before they were transferred to the TFH for final rearing.

Tucannon Fish Hatchery

The TFH is supplied with three different water sources. River water is captured from the Tucannon River and ranges in temperatures from 0.6-15.6° C during use by the hatchery. The intake is located 0.81 km upstream of the hatchery. Water from the intake travels down an open channel into Rainbow Lake. Rainbow Lake functions as a reservoir to provide the hatchery with cooler water in the summer months and warmer water in the winter months. It also provides a pool of water to draw from when encountering adverse intake conditions, resulting in temporary loss of water flows. The water right for this source is 453 L/sec. From the outlet of Rainbow Lake the water travels through a 45.7 cm above ground pipeline to the hatchery. Well water is pumped from two separate sources to an aeration tower, and then gravity fed to the rearing units and the domestic pump building. The combined well water right is 56.6 L/sec, with well #2 running between 12.2-13.9° C and well #3 running a constant 16.1° C. Spring water is pumped from an underground collection site to the same aeration tower and gravity fed to the rearing units. The water right for this source is 150 L/sec, and has a stable temperature of 10.6-11.1° C.

The vessels used for rearing the captive progeny at TFH were three concrete round ponds approximately 12.2 m in diameter with a maximum of 79.8 m^3 of rearing area each, two concrete 3.1 x 24.4 x 0.9 m raceways, and one concrete 4.6 x 41.5 x 1.5 m raceway. The number and size of vessels used was dependent on the total number on hand for each release year.

Curl Lake AP is located along the Tucannon River 8 km upstream of the Tucannon Hatchery. It is an earthen pond holding approximately 23,520 m^3 of water. It has a water right of 169.9 L/sec and is supplied with water from the Tucannon River through a gravity water supply system. Water temperatures during the acclimation period range from 1.1-8.9°C.

Pond Densities

The WDFW Fish Health Specialist has established pond density guidelines for Chinook. The suggested maximum density index (DI) for Chinook is 1.25 $kg/m^3/cm$. Fish reared above the density index are at a greater risk of disease.

The number of juveniles being transferred from LFH each year would determine which rearing vessels would be utilized to keep the DI level as low as possible. The average loading DI upon receiving fish was 0.52 $kg/m^3/cm$. The fish were reared for approximately four months at the TFH. Prior to transfer to Curl Lake AP, the highest DI averaged 0.64 $kg/m^3/cm$.

Feed

For the 2000-2004 brood years, once the captive progeny juveniles were transferred to the TFH they were fed a Bio Moist Feed. This diet had 20% moisture content. Because of estimated size target goals at transfer to Curl Lake AP, precocial male concerns, rearing timeframe, and proven palatability with Chinook, we thought this would be the best diet to use. Once the fish were transferred to Curl Lake AP they were fed Clarks dry diet since food is delivered with the use of a blower feeder that does not work well with moist feeds. For the 2005-2006 brood years, due to the discontinuation by the manufacturer of the Bio Moist Feed, fish were fed the Clarks fry diet from arrival at the TFH and at Curl Lake AP. Feed conversion rates averaged 0.75 kg fed to 0.45 kg flesh gain at the TFH. Food conversion averaged 0.29 kg feed fed to 0.45 kg flesh gain at Curl Lake AP.

Water

At the TFH, juveniles were reared on surface water as long as the temperatures stayed above 3° C. In the mid 1990s the conventional hatchery fish had been identified having low levels of Erythrocytic Inclusion Body Syndrome (EIBS) virus. EIBS causes severe anemia and the length of infection is temperature dependent, with shorter durations at higher temperatures. The recommendation of the WDFW Fish Health Specialist was to turn on a mixture of well/spring water with the river water in the winter months to keep it close to 4.4° C. This would allow the fish's immune system to aid fighting off the virus. This procedure has been applied during the rearing of Chinook salmon ever since. Typically mid-December through late January is when well and spring water is mixed with river water to keep the temperatures at a desired level. Once the fish have been moved up to Curl Lake AP they are reared exclusively on surface river water.

Target Sizes

For the 2000-2004 brood years, the plan was to mimic the size at release goal of the conventional supplementation fish at 30 g. The target size at transfer to Curl Lake AP from TFH in February of each year was 25 g to project a release size of 30 g. For the 2005-2006 brood years, the release goal was changed to a release size of 50 g from Curl Lake AP in an attempt to increase survival and return rates. The target size at transfer to Curl Lake AP for 50 g fish from TFH was 35-38 g for those two brood years.

Health of Captive Broodstock

Overall survival of the captive fish was good with mortality of immature fish from age-1 to maturation for the five brood years ranging from 3.2% to 16.9% (Table 1; Appendix C). The 1997 brood year experienced the highest mortality due to external fungus following sorting. With subsequent brood years, formalin treatments were initiated immediately following handling and mortality was substantially reduced.

Table 1. Total mortalities of immature fish from ages one to five prior to maturation of the Tucannon River spring Chinook captive broodstock at Lyons Ferry Hatchery.

	Number at	Mortality			
Brood Year	Age 1	Male	Female	Total	Percent
1997	433	22	51	73	16.9
1998	438	13	18	31	7.1
1999	409	7	6	13	3.2
2000	450	6	12	18	4.0
2001	450	10	21	31	6.9

BKD was not observed in the captives, thus supporting the selection criteria used in founding. Also, BKD-ELISA testing of female captives at spawning also showed that the captive brood was not infected (Table 2).

Table 2. BKD-ELISA testing of female Tucannon River spring Chinook captive broodstock at Lyons Ferry Hatchery.

		Below Low		Low		Moderate		High	
Year	Number	No.	%	No.	%	No.	%	No.	%
2000	12	11	91.7	1	8.3	0	0.0	0	0.0
2001	166	165	99.4	1	0.6	0	0.0	0	0.0
2002	122	122	100.0	0	0.0	0	0.0	0	0.0
2003	224	224	100.0	0	0.0	0	0.0	0	0.0
2004	135[a]	135	100.0	0	0.0	0	0.0	0	0.0
2005	167	167	100.0	0	0.0	0	0.0	0	0.0
2006	86	86	100.0	0	0.0	0	0.0	0	0.0

[a] Some samples lost during 2004.
Below-Low = <0.10; Low = 0.11-0.199; Moderate = 0.2-0.45; High = >0.45

Health of Captive Broodstock Progeny

Most brood years of Tucannon River Chinook captive progeny were healthy throughout their rearing at LFH and TFH and upon release. The only exception was the 2001 brood year. Bacterial kidney disease was diagnosed for that brood year in November 2002 and chronic mortality continued throughout the rearing cycle. The fish were treated with erythromycin medicated feed and mortality declined following treatment. The 2001 brood year Chinook could have been infected horizontally by the use of the river water supply at the TFH, or by cross-infection from spring or fall Chinook at LFH.

Monitoring and Evaluation

Background

As previously mentioned, the LSRCP Tucannon River Chinook conventional hatchery program performed ongoing evaluations of the natural, conventional hatchery, and captive populations during the captive program. Some of the monitoring and evaluation activities include or have included: smolt release sampling, smolt trapping, spawning ground surveys, genetic monitoring, snorkel surveys for juvenile population estimates, spawning, fecundity monitoring, and experimental release strategies for smolts. Through these and other activities, survival rates of the natural, conventional hatchery, and captive origin fish have been documented. These and other activities will continue to play a major role in evaluating the captive program in the future (for both parents and progeny) and determine the program's success or failure. The last captive progeny are expected to return in 2011. The following are the results through 2008.

Statistical analysis

Analysis of variance (ANOVA) was used to test for significant differences among the means for data with normal distributions. Percent data was arcsine transformed for normality prior to analysis (Zar 1996). Multiple range tests were then used to determine which means were significantly different. A nonparametric Kruskal-Wallis test was employed to test for significant differences among multiple medians for data sets with nonnormal distributions. Notched box-and-whisker plots were then used to determine which individual medians were statistically different from each other. If two notches for any pair of medians overlap, there is not a statistically significant difference between those two medians. If the two notches for any pair of medians do not overlap, there is a statistically significant difference between the medians. All statistical tests were performed at the 95% confidence level.

Spawn Timing

Spawn timing of natural, conventional hatchery, and captive origin fish was followed through the duration of the captive program. Captive female spawn timing was generally two weeks later than natural and hatchery origin fish collected from the Tucannon River (Figure 5). Mature captives were held upstream of broodstock collected from the river in 2003 to address possible disease concerns, however, spawn timing appeared to be adversely affected (Gallinat 2004). For the rest of the program's duration, mature captives were held downstream of fish collected from the river.

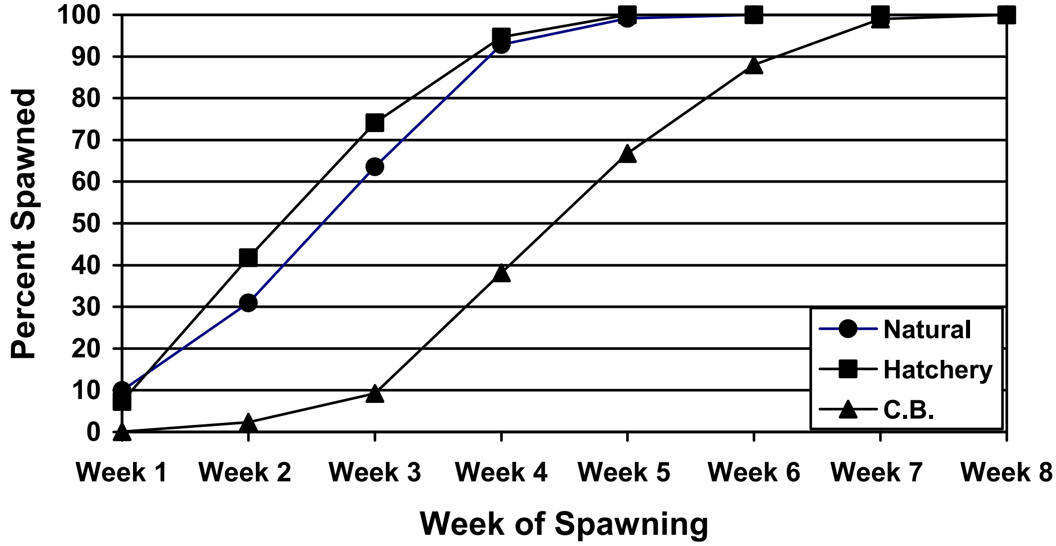

Figure 5. Mean spawn timing comparison of natural, conventional hatchery, and captive (C.B) origin ripe females for the 2000-2006 spawning years.

Although the captive fish were reared outdoors under natural photoperiod conditions, the water temperature does not fluctuate as it does in nature and remains a constant 11° C due to the use of well water at LFH. Feed levels in the hatchery environment also do not vary as they would in nature. Although spawn timing was about two weeks later, we were able to spawn captive females with natural and hatchery-origin males during the beginning of each spawning season (Table 3).

Table 3. Number of viable captive females and natural-origin, conventional hatchery, and captive males that were spawned during the captive program. (Some natural-origin males were spawned more than once.)

Spawn Year	Captive Females[a]	Natural Males	Hatchery Males	Captive Males	Total Parents
2000	12	5	0	8	25
2001	166	23	0	83	272
2002	121	21	9	83	234
2003	223	19	1	132	375
2004	205	20	0	139	364
2005	167	22	25	33	247
2006	86	17	24	0	127

[a] Does not include females that were green/non-viable or spawned out and killed outright.

Age Composition

Both male and female Chinook that reared in the hatchery environment for the captive program matured and spawned at younger ages than conventional hatchery and natural-origin fish (Figure 6). The majority of captive males matured at age-3 compared to age-4 for conventional hatchery and natural origin males collected from the river (Figure 6).

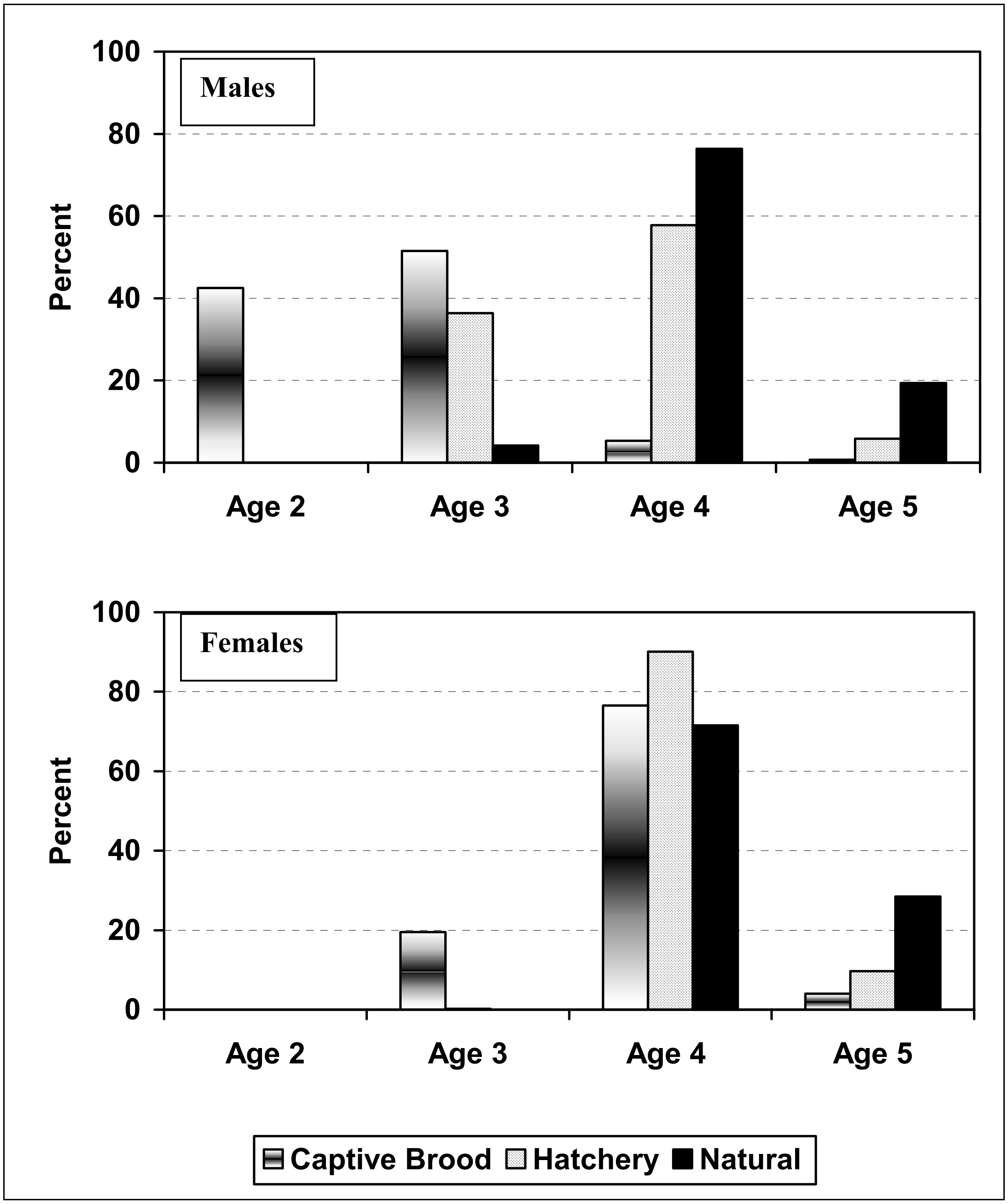

Figure 6. Age composition at maturity for male and female captive, conventional hatchery, and natural origin Tucannon River spring Chinook.

The majority of females from all origins matured at age-4 with captive spawners having few age-5 females in the spawning population (Figure 6). This suggests there is a strong environmental component to maturity at age. The hatchery environment, with warmer water temperatures and abundant food supply, allows for faster growth that results in earlier maturation. Larsen et al. (2006) found they could adjust the precocity rate of male hatchery-reared salmon by modulating growth during certain times of the year. This method could possibly be employed to reduce the amount of early maturation in captive programs.

Age-4 Female Comparisons

Age-4 females were the dominant age class for all three populations. Hence, we focused comparisons of reproductive traits on females from this age group.

Fork Length

Mean fork length of age-4 captive brood females spawned from 2001-2006 was 53 cm compared to 69 and 71 cm for age-4 conventional hatchery and natural origin females, respectively. There was a statistically significant difference amongst the medians for all three groups at the 95% confidence level (Figure 7).

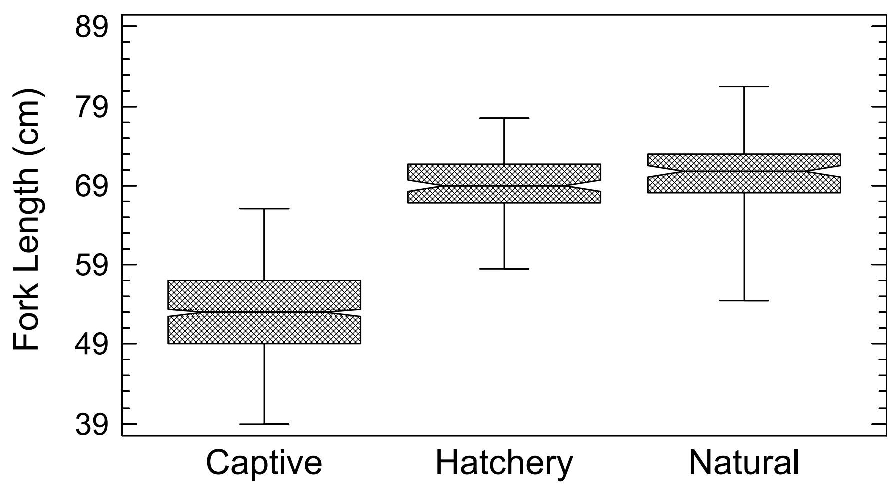

Figure 7. Notched box-and-whisker plots of fork length (cm) for age-4 captive, conventional hatchery, and natural origin spawned females, 2001-2006.

Egg Size and Eye-up Mortality

Mean egg size of age-4 captive fish was 0.256 g/egg compared to mean egg sizes of 0.234 and 0.230 g/egg for age-4 conventional hatchery and natural origin females, respectively. There was a statistically significant difference ($P < 0.05$) between median egg size of the captives and the median egg size of conventional hatchery and natural origin fish (Figure 8).

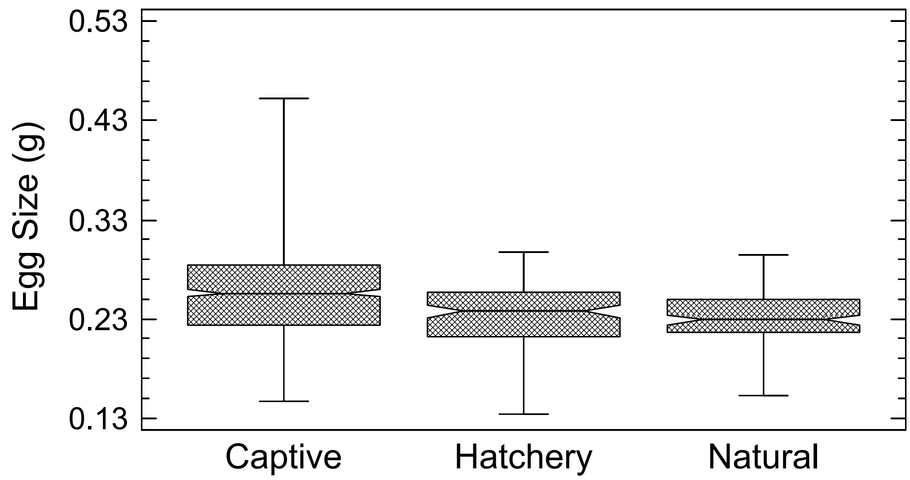

Figure 8. Notched box-and-whisker plots of egg size (g) for age-4 captive, conventional hatchery, and natural origin spawned females, 2001-2006.

Despite their smaller size on average, age-4 captive females had significantly larger eggs. This contradicts a study in British Columbia on farmed Chinook salmon by Heath et al. (2003), who found that hatchery rearing relaxes natural selection favoring large eggs, allowing fecundity selection to drive rapid evolution of small eggs. They stated that these small eggs could lead to reduced survival and limit the success of hatchery programs. However, Beacham (2003) points out that Heath and his colleagues incorrectly attributed an ocean environmental effect and female variation on egg size to a genetic change as a result of hatchery enhancement. The broodstock they studied was also developed to satisfy a niche market and matures at a much smaller size and has unusually small eggs (Beacham and Murray 1993; Beacham 2003). It was also not clear if the British Columbia hatchery incorporated wild broodstock into their captive commercial hatchery population.

In an earlier work, Heath et al. (1999) found egg size was positively correlated with early survival, but negatively correlated with fecundity. Kinnison et al (2001) also found that egg size is strongly correlated with initial offspring (fry) size in salmonids and offspring size is in turn correlated with survival in salmon. They found that a proportionate increase (or decrease) in fry size results in more than an equivalent change in fry-to-adult survival. Heath et al. (1999) however, found that progeny hatched from small eggs grew faster than progeny hatched from large eggs. If this were true, then any survival advantage there was for investing energy into large eggs could be nullified by producing a greater number of smaller eggs. Large egg size did not appear to increase survival in our study since mortality to eye-up was 49% for captive brood eggs, compared to eye-up mortalities of 4% and 3% for conventional hatchery and natural origin fish, respectively. Quality of sperm was determined not to be a factor in the mortality of eggs (Gallinat 2006). The high egg mortality for captive fish may be related to unknown environmental, physiological, or dietary factors.

Tucannon River Chinook migrate 622 kilometers from the mouth of the Columbia River to the mouth of the Tucannon River (Stein 1998). This long migration may help explain the difference in egg size between the migrating natural and conventional hatchery fish and the non-migrating captive salmon. Beacham and Murray (1993) and Healey (2001) suggested that a limited amount of energy could be expended on egg production on more northern stocks and stocks with long freshwater migrations. Kinnison et al. (2001) also concluded that migration in salmon not only cost the fish in energy reserves, but was also expressed as a cost to ovarian investment, primarily in egg size. Thus, captive fish may be able to reallocate more energy into producing larger eggs due to a readily available food supply and the fact they are non-migratory during the maturation period.

Fecundity

For captives, the large egg size in small fish resulted in very low fecundity compared to conventional hatchery and natural origin fish collected from the Tucannon River. Mean fecundity of age-4 captive brood females was 1,664 eggs/female compared to age-4 conventional hatchery (2,952) and natural origin (3,381) females spawned from 2001-2006. There was a statistically significant difference ($P < 0.05$) among median fecundities for all three groups of fish (Figure 9).

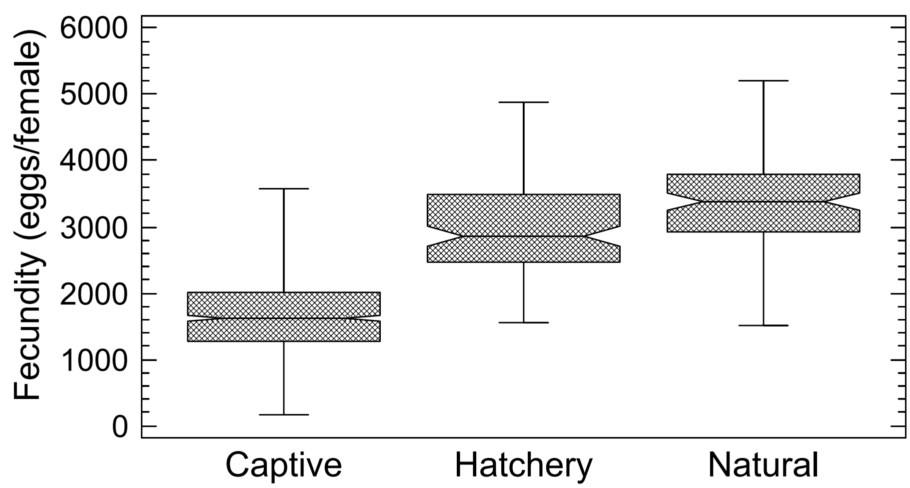

Figure 9. Notched box-and-whisker plots of fecundity for age-4 captive, conventional hatchery, and natural origin spawned females, 2001-2006.

Relative Fecundity

Relative fecundity was used to correct for the effect of body size on the number of eggs produced by each female. Relative fecundity was calculated by dividing total fecundity by body weight (kg), since given fish of equal length, the fish with the larger girth could potentially hold more eggs.

Mean relative fecundity of age-4 captive fish was 779 eggs/kg and was lower compared to the relative fecundities of 836 and 881 eggs/kg for age-4 conventional hatchery and natural origin females, respectively. There was a statistically significant difference ($P < 0.05$) among the median relative fecundities for all three groups of fish (Figure 10).

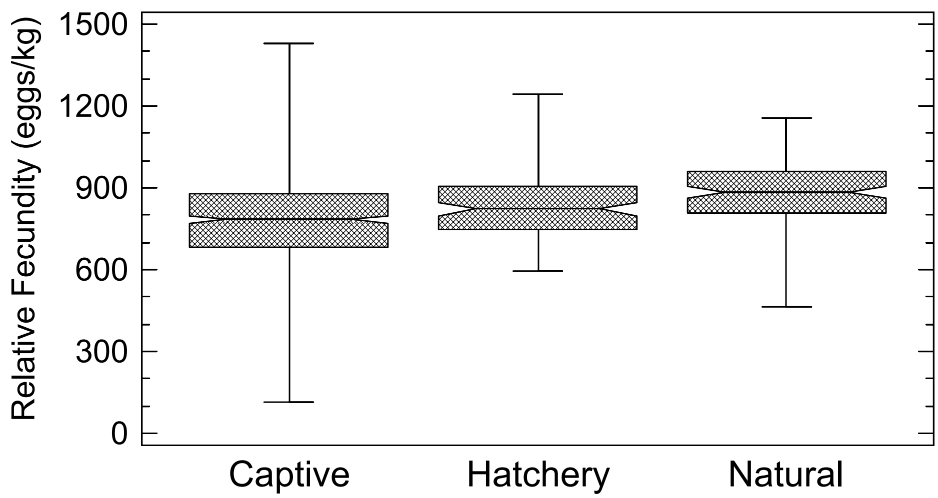

Figure 10. Notched box-and-whisker plots of relative fecundity for age-4 captive, conventional hatchery, and natural origin spawned females, 2001-2006.

Reproductive Mass

Female salmon may allocate similar amounts of reproductive effort but partition it differently (e.g., small eggs and high fecundity may be equal in energy expenditure to large eggs and low fecundity). In order to account for differences in fecundity caused by egg size, reproductive mass was calculated by multiplying fecundity by egg size to provide total reproductive contribution in grams.

Mean reproductive mass of age-4 captive brood females was 426 g and was considerably lower compared to the mean reproductive mass of conventional hatchery (689 g) and natural (778 g) origin females. There was a statistically significant difference ($P < 0.05$) among the median reproductive mass of the captives and the median reproductive mass of conventional hatchery and natural origin fish (Figure 11).

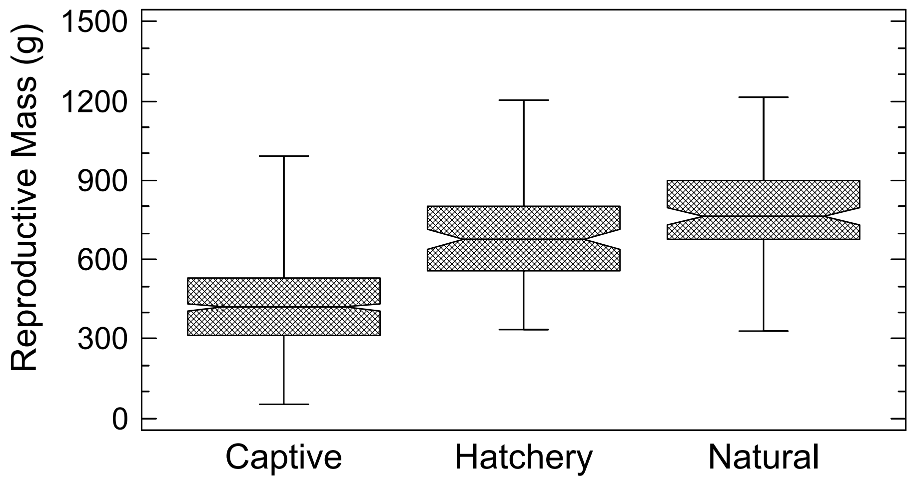

Figure 11. Notched box-and-whisker plots of reproductive mass for age-4 captive, conventional hatchery, and natural origin spawned females, 2001-2006.

Adult Outplants

During 2002, based on the number of mature captive adults available, it was estimated that we would likely be in excess of our approved release goal of 150,000 smolts. To stay within the allowed release goal, WDFW decided to release excess mature captives into the Tucannon River just prior to spawning. On 20 August 2002, 97 (21 1998 BY and 76 1999 BY) excess adults were released into the Tucannon River at Panjab Bridge (rkm 74.5). All released fish were tagged with metal (Monel) jaw tags and radio transmitters were inserted into ten of the larger (presumably female) fish for tracking and monitoring in the wild. Radio tagged fish were monitored weekly through the end of September (Appendix D). Table 4 summarizes the tagging and recovery information from the radio tagged fish. Two of the radio tagged females spawned successfully within 2 km of the release site (9/165 and 9/192). Another female (9/167) that was attempting to spawn (actively digging a redd) died after releasing less than 10% of her eggs. Of the remaining seven fish: three tags were recovered on the stream bank without a carcass and may have been illegally harvested; two fish were eaten by predators; one fish was a prespawn mortality unrecoverable in a debris jam; and one fish (9/203) was never located after release – the radio stopped transmitting or the fish and transmitter left the area.

Table 4. Radio tagging and recovery data for ten adult captive Chinook tagged on 16 July and released on 20 August at Panjab Bridge in the Tucannon River during 2002.

Release Data				Recovery Data			
Channel/ Code	Panjab Br. Rkm	Sex	FL (cm)	Recovery Information	Date	Rkm	Spawned?
9/165	74.5	F	58.0	Recovered fish & tag	9/25	72.9	Yes
9/167	74.5	F	55.5	Recovered fish & tag	9/13	73.0	No
9/171	74.5	F	56.5	Recovered fish & tag	9/23	73.4	No
9/179	74.5	F	55.5	Tag found on bank	9/20	77.7	No
9/183	74.5	F	52.0	Tag found on bank	9/20	74.5	No
9/184	74.5	F	51.0	Carcass in log jam	---	68.7	No
9/192	74.5	F	50.0	Recovered fish & tag	9/27	73.6	Yes
9/193	74.5	F	51.0	Tag in animal den	---	73.5	No
9/203	74.5	F	49.0	Lost contact	---	---	Unknown
9/205	74.5	F	47.0	Tag found on bank	9/13	76.6	No

Outplanted adults differed from natural and hatchery-origin fish in the river in morphology and coloration. Captive males lacked a prominent kype and captive fish were more golden-yellow in color. During redd surveys, released captive adults were observed being chased by more dominant male and female natural and hatchery-origin fish in the river.

In studies by Berejikian et al. (1997), wild coho females produced more nests than captive females. They also found that captive coho males were dominated by wild males and were also attacked more often by females than wild males. Fleming and Gross (1993) found coho hatchery females were delayed in spawning, retained more eggs, spawned in less desirable areas, and were less successful in guarding nest sites.

Losses to predation may be higher for fish released from a hatchery environment due to inability to accurately assess predation risks, secondary stress effects, and a general unfamiliarity with their new surroundings (Steward and Bjornn 1990).

Due to the low frequency of natural spawning by released fish, high mortality due to predation and presumed illegal harvest, and higher egg mortality in the hatchery during 2002 than predicted, the priority for excess fish was changed. The co-managers agreed to spawn the excess adults and release their progeny as parr.

Juvenile Releases

Number of parr and smolts released from the captive broodstock program is provided in Appendix E. The captive program provided a boost in the number of smolts released that otherwise would not have occurred had the program not been in place (Figure 12).

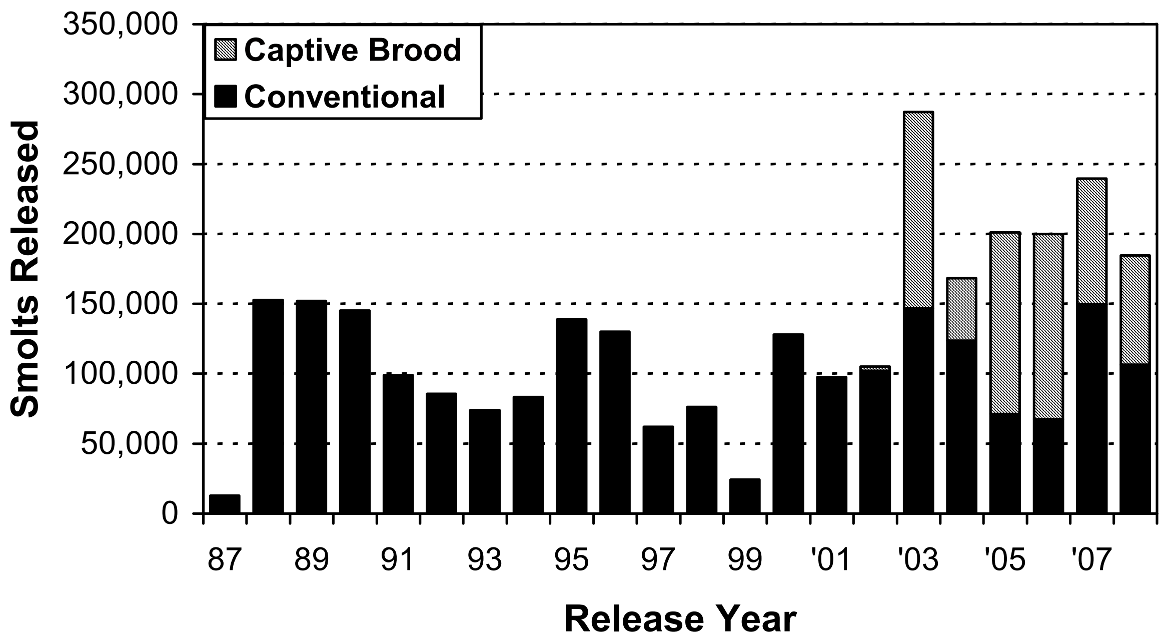

Figure 12. Number of captive progeny and conventional hatchery smolts released by year (1987-2008).

PIT Tagging

We used passive integrated transponder (PIT) tags to compare emigration travel timing and relative success of the captive progeny with our conventional hatchery fish for the 2001-2006 brood years. Due to the small number of captive progeny released, the 2000 brood year was not PIT tagged for comparisons with the conventional hatchery fish. The goal for each brood year was to tag 1,000 captive progeny and 1,000 conventional hatchery fish during early February before transferring them to Curl Lake AP for acclimation and volitional release (Appendix F). Mortalities after tagging were low, although some minor delayed mortality may have occurred after transfer. Detection rates at Snake and Columbia river dams were always higher for conventional hatchery fish compared to captive progeny but differences were not significant, with the exception of the 2006 brood year (Appendix F). The difference may be sample size related for the 2006 brood year.

Survival probabilities were estimated by the Cormack Jolly-Seber methodology using the Survival Under Proportional Hazards (SURPH) 2.2 computer model. The data files were created using the PitPro version 4.1 computer program to translate raw PIT Tag Information System (PTAGIS) data of the Pacific States Marine Fisheries Commission into usable capture histories for the SURPH program. As with the total detection rates, survival probabilities were always higher for the conventional hatchery fish compared to the captive progeny (Table 5). With the exception of the 2006 brood year, differences were not significant ($P > 0.05$). Since both groups were raised in the same manner and released at similar sizes, differences may be related to hatchery domestication effects or other unknown factors.

Table 5. Survival probabilities from Curl Lake Acclimation Pond (rkm 65.6) to Lower Monumental Dam for conventional hatchery and captive progeny Tucannon River spring Chinook salmon for the 2001-2006 brood years.

Brood Year	Origin	Number Tagged	Survival Probability	S.E.
2001	Conventional Hatchery	1,010	0.62	0.06
2001	Captive Brood	1,007	0.55	0.06
2002	Conventional Hatchery	1,012	0.53	0.12
2002	Captive Brood	1,029	0.50	0.11
2003	Conventional Hatchery	993	0.45	0.04
2003	Captive Brood	993	0.44	0.05
2004	Conventional Hatchery	1,001	0.84	0.08
2004	Captive Brood	1,002	0.83	0.08
2005	Conventional Hatchery	1,002	0.68	0.05
2005	Captive Brood	1,000	0.61	0.06
2006	Conventional Hatchery	2,498	0.30*	0.02
2006	Captive Brood	997	0.13*	0.02

* Statistically Significant Difference, $P < 0.05$.

Survival Rates

Point estimates of population sizes have been calculated for various life stages (Appendix G) of natural, conventional hatchery and captive origin fish based on fecundity estimates, hatchery records, smolt trapping and redd surveys. From these data, survivals between life stages have been calculated to assist in evaluation of the captive program (Table 6).

Table 6. Percent survival by life stage of progeny from naturally reared, conventional hatchery reared, and captive reared Tucannon River spring Chinook salmon for the 2000-2006 brood years.

	Natural			Conventional Hatchery			Captive Brood		
Brood Year	**Egg to Parr**	**Parr to Smolt**	**Egg to Smolt**	**Egg to Parr**	**Parr to Smolt**	**Egg to Smolt**	**Egg to Parr**	**Parr to Smolt**	**Egg to Smolt**
2000	13.8	44.9	6.2	95.6	82.8	79.2	29.7	70.7	21.0
2001	6.1	60.1	3.6	95.0	84.0	79.8	69.4	71.9	49.9
2002	6.7	83.8	5.7	89.5	81.6	73.0	28.6	88.7	25.4
2003	9.1	56.2	5.1	89.9	56.3	50.6	53.3	78.9	42.0
2004	6.0	68.3	4.1	91.8	52.4	48.1	45.3	93.9	42.6
2005	5.8	83.1	4.8	93.9	98.7	92.6	35.9	95.8	34.4
2006	---[a]	---[a]	10.7	90.9	94.8	86.2	48.8	98.4	48.0
Mean	7.9	66.1	5.7	92.4	78.6	72.8	44.4	85.5	37.6
S.D.	3.1	15.4	2.3	2.5	17.8	17.2	14.5	11.6	11.1

[a] A snorkel survey was not performed to allow an estimate of parr for the 2006 brood.

Egg-to-parr survival for captive progeny averaged 44.4% over seven years (Table 6). This is higher than the 7.9% egg-to-parr survival estimated for in-river natural-origin Tucannon River Chinook due to their protection in the hatchery environment, but was significantly ($P < 0.05$) less than the 92.4% survival from the conventional hatchery fish. Parr-to-smolt survival averaged 85.5% for the captive brood progeny and was not significantly different ($P > 0.05$) from natural origin and conventional hatchery fish. Egg-to-smolt survival was 37.6% for the captive fish and was significantly ($P < 0.05$) higher than natural-origin fish (5.7%) but significantly ($P < 0.05$) lower than conventional hatchery-origin fish (72.8%).

Smolt-to-adult survival for captive progeny has averaged 0.02% for the first five years of the program (Table 7) and was significantly ($P < 0.05$) less than the SARs of 0.13% and 1.07% for conventional hatchery and natural-origin fish, respectively. Due to the very poor adult returns of the captive progeny from earlier releases, size at release was increased to 50 g/fish beginning with the 2005 brood year in an attempt to increase juvenile survival and return more adults back to the Tucannon River (Table 7).

Table 7. Comparisons of adult returns and smolt-to-adult (SAR) returns of natural, conventional hatchery, and captive origin Tucannon River spring Chinook salmon for the 2000-2005 brood years (2004 and 2005 incomplete returns).

Natural Origin						
					SAR (%)	
Brood Year	**Number of Smolts**	**Expanded No. Age 3**	**Expanded No. Age 4**	**Expanded No. Age 5**	**w/ Jacks**	**No Jacks**
2000	20,045	3	392	51	2.22	2.21
2001	38,079	0	235	9	0.64	0.64
2002	60,530	3	124	75	0.33	0.33
2003	23,003	7	115	51	0.75	0.72
2004	21,057	8	352	---	1.71	1.67
2005	17,579	131	---		0.75	---
Mean					**1.07**	**1.11**

Conventional Hatchery Origin						
					SAR (%)	
Brood Year	**Number of Smolts**	**Expanded No. Age 3**	**Expanded No. Age 4**	**Expanded No. Age 5**	**w/ Jacks**	**No Jacks**
2000	102,099	26	131	0	0.15	0.13
2001	146,922	19	105	1	0.09	0.07
2002	123,586	6	98	16	0.10	0.09
2003	71,154	2	65	4	0.10	0.10
2004	67,542	18	98	---	0.17	0.15
2005	149,466	291	---		0.19	---
Mean					**0.13**	**0.11**

Captive Brood Origin						
					SAR (%)	
Brood Year	**Number of Smolts**	**Expanded No. Age 3**	**Expanded No. Age 4**	**Expanded No. Age 5**	**w/ Jacks**	**No Jacks**
2000	3,055	0	0	0	0.00	0.00
2001	140,396	3	14	0	0.01	0.01
2002	44,784	0	2	0	0.00	0.00
2003	130,064	2	19	0	0.02	0.01
2004	132,312	0	82	---	0.06	0.06
2005	90,056	158	---		0.18	---
Mean					**0.05**	**0.02**

Based on adult returns from the 2000-2005 broods, captives produced only 0.17 adults for every spawner, which was significantly ($P < 0.05$) lower than naturally reared salmon that produced 0.67 adults for every spawner (Table 8). Conventional hatchery reared fish produced 1.66 adults per spawner and was the only group above replacement levels.

While the captive progeny will continue to return until 2011, based on results to date, the Tucannon River Chinook captive program has been unsuccessful in almost every year in meeting the adult return goals of the program. We are cautiously optimistic that the change in size at release beginning with the 2005 brood year will increase SAR survival and improve adult returns for the final years of the program.

Table 8. Parent-to-progeny survival estimates of Tucannon River spring Chinook salmon for the 2000-2005 brood years (2004 and 2005 brood years incomplete).

	Natural			**Conventional Hatchery**			**Captive Brood**		
Brood Year	No. of Spawners	No. of Returns	Return/ Spawner	No. of Spawners	No. of Returns	Return/ Spawner	No. of Spawners	No. of Returns	Return/ Spawner
2000	239	446	1.87	73	157	2.15	25	0	0.00
2001	894	244	0.27	104	125	1.20	272	17	0.06
2002	897	202	0.23	93	120	1.29	234	2	0.01
2003	366	173	0.47	75	71	0.95	375	21	0.06
2004	480	360	0.75	88	116	1.32	364	82	0.23
2005	317	131	0.41	95	291	3.06	247	158	0.64
Mean			**0.67**			**1.66**			**0.17**
S.D.			**0.62**			**0.80**			**0.25**

Termination of the Program

While the Tucannon River Chinook captive program did produce additional smolts for release, the program has performed poorly to date compared with our conventional hatchery supplementation program. Captive programs of Pacific salmon have been plagued with high mortality rates, inappropriate spawn timing, precocious maturation of males, low egg viability, and captive adults that are smaller than wild fish (Flagg and Mahnaken 1995; Schiewe et al. 1997). The Tucannon River spring Chinook captive broodstock program was ended because of the following reasons:

- The program had a specific endpoint from the beginning as it was designed to last for only one generation (five brood years).
- Success of the program did not meet our goals and did not match or enhance the conventional hatchery supplementation program.
- WDFW has concerns about continued severe hatchery intervention and long-term effects on the population.
- Natural production/adults increased regardless of the lack of adult returns from the captive program (Figure 13).

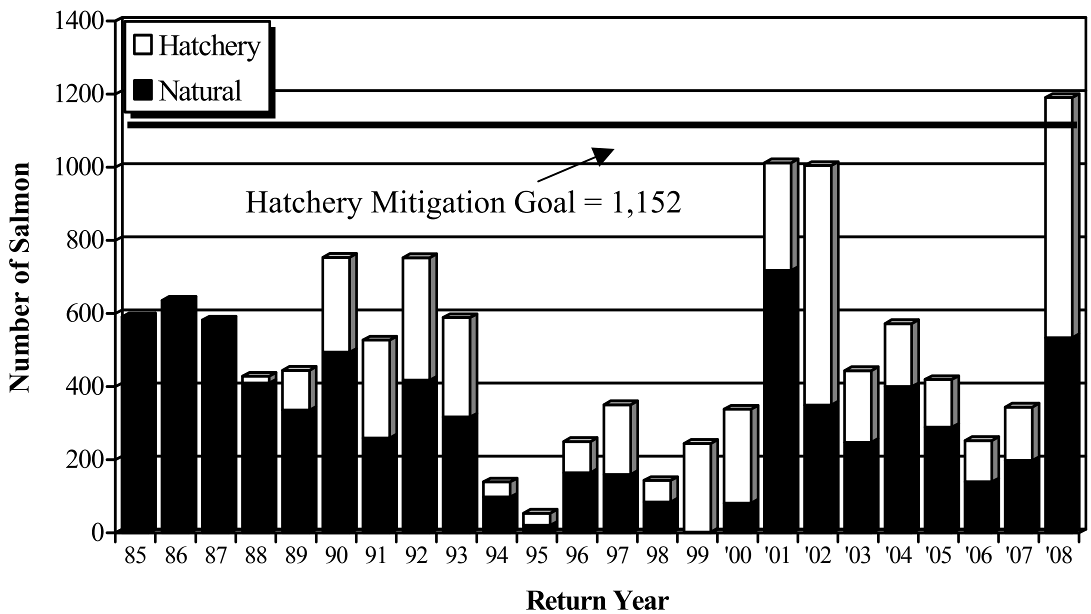

Figure 13. Total estimated escapement for Tucannon River spring Chinook salmon for the 1985-2008 run years.

Conclusions and Recommendations

The WDFW LSRCP evaluation program will continue to document returning adults from the captive program and compare their survival to survivals from the conventional hatchery program and natural origin fish. The major conclusions and recommendations for the Tucannon captive program are as follows:

- Selecting fry from parents based on Bacterial Kidney Disease (BKD) screening benefited the program, as BKD was not a problem with the Tucannon captives unlike other captive programs that collect eggs/fry from the wild.
- Size of the captive adults were significantly smaller than conventional hatchery and natural origin adults and egg quality was poor with high egg mortality. This may be due to unknown environmental, physiological, or dietary factors. More research should be conducted on the nutrition and growth requirements of Chinook salmon that are captively reared.
- By selecting fry from the conventional hatchery program, effective population size of the Tucannon River Chinook salmon broodstock was generally above 50 without removing additional fish from the river.
- The captive program did provide additional smolts for release that otherwise would not have been produced without the program.
- The release of excess captive adults into the natural environment to spawn on their own is not recommended as the fish are raised in a protected hatchery environment and appear to lack the necessary skills to survive in the wild.
- Adult returns from the program to date have been poor in comparison to the conventional hatchery program and have failed to return the 300 adults expected per year. It is unknown whether hatchery domestication effects or other unknown factors have played a role in the poor returns, as the captive progeny and conventional hatchery fish are reared and released in the same manner. Captive progeny size at release was increased from 30 g/fish to 50 g/fish for the 2005 and 2006 brood years and we are cautiously optimistic this change will increase SAR survival.
- Because of the small size, low fecundity, and poor egg quality from the captive adults, and poor returns of captive progeny, the co-managers decided to increase the release goal of the conventional hatchery supplementation program from 132,000 to 225,000 yearling smolts instead of attempting to continue with the Tucannon River Chinook captive program.

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APPENDIX A

Table 1. Selection of progeny for the Tucannon River spring Chinook captive broodstock program based on origin, crosses, and BKD ELISA results, 1997 and 1998 BYs.

Brood Year	Eggtake Date	Female Numbers	Male Numbers	Crosses	BKD ELISA[1]	Tank/Family Number
97	09/16	H885 + H886	W108 + W110	Mixed	LOW, BL	TANK 1
97	09/16	H889	W116 + W120	Mixed	BL	TANK 2
97	09/23	W958 + W957	H122 + H123	Mixed	BL	TANK 3
97	09/16	W897 + W898	H156 + H199	Mixed	BL	TANK 4
97	09/09	H872 + H871	W159 + W161	Mixed	BL	TANK 5
97	09/09	H873	W163 + W165	Mixed	LOW	TANK 6
97	09/09	W881 + W882	H167 + H175	Mixed	BL	TANK 7
97	09/16	W951 + W952	H149 + H157	Mixed	BL	TANK 8
97	09/09	W874 + W875	H171 + H173	Mixed	BL	TANK 9
97	09/09	W878 + W876	H179 + H181	Mixed	LOW, BL	TANK 10
97	09/02	W869 + W867	H191 + H193	Mixed	BL	TANK 11
97	09/09	H879	W169 + W177	Mixed	BL	TANK 12
97	09/16	W899	H153 + H154	Mixed	BL	TANK 13
97	09/02	W870	H183 + H185	Mixed	BL	TANK 14
97	09/02	H868	W187 + W189	Mixed	BL	TANK 15
98	08/25	W1003 + W1004	H754 + H753	Mixed	BL	TANK 1
98	08/25	W1005 + W1006	H751 + W131	Mixed	LOW, BL	TANK 2
98	09/08	W3001 + W3002	H758 + H759	Mixed	LOW, BL	TANK 3
98	09/08	W3003 + W3004	H755 + H756	Mixed	BL	TANK 4
98	09/08	W3005 + W3006	H757 + H760	Mixed	BL	TANK 5
98	09/08	W3007 + W3008	W128 + W129	Natural	BL	TANK 6
98	09/08	H3009 + H3010	W130 + W133	Mixed	LOW, BL	TANK 7
98	09/11	H4001 + H4002	W135 + W134	Mixed	LOW, BL	TANK 8
98	09/11	W4003 + W4004	H762 + H761	Mixed	LOW, BL	TANK 9
98	09/11	W4007 + W4008	H767 + H765	Mixed	LOW, BL	TANK 10
98	09/11	W4009 + W4010	H769 + H768	Mixed	BL	TANK 11
98	09/15	W5002	H777 + H773	Mixed	LOW	TANK 12
98	09/15	W5003	H772 + H771	Mixed	LOW	TANK 13
98	09/22	W6005 + W6006	H781 + H780	Mixed	BL	TANK 14
98	09/22	W6007 + W6008	H783 + H782	Mixed	BL	TANK 15

[1] Low = 0.11-0.19 Optical Density; Below Low = < 0.11 Optical Density.

Table 2. Selection of progeny for the Tucannon River spring Chinook captive broodstock program based on origin, crosses, and BKD ELISA results, 1999 and 2000 BYs.

Brood Year	Eggtake Date	Female Numbers	Male Numbers	Crosses	BKD ELISA[1]	Tank/Family Number
99	08/31	H101	H1+H2+H526	Hatchery	LOW	TANK 1
99	09/07	H203	H12+H13+H536	Hatchery	BL	TANK 2
99	09/07	H204	H15+H530+H531	Hatchery	LOW	TANK 3
99	09/07	W205	H18+H532+H533	Mixed	LOW	TANK 4
99	09/07	H206	H528+H529+H534	Hatchery	BL	TANK 5
99	09/07	H212	H19+H20	Hatchery	BL	TANK 6
99	09/14	H305	W31+H571	Mixed	LOW	TANK 7
99	09/14	H306	W21+H576	Mixed	LOW	TANK 8
99	09/14	H307	H40+H550	Hatchery	LOW	TANK 9
99	09/14	H309	H23+H549	Hatchery	BL	TANK 10
99	09/14	H310	H39+H572	Hatchery	LOW	TANK 11
99	09/14	H311	H36+H568	Hatchery	LOW	TANK 12
99	09/14	H312	H24+H544	Hatchery	LOW	TANK 13
99	09/21	H403	H45+H580	Hatchery	LOW	TANK 14
99	09/21	H404	H581+H582+H583	Hatchery	LOW	TANK 15
00	8/29	H102	H1 + H2	Hatchery	BL	TANK 1
00	8/29	H103 + H104	H3 + H4	Hatchery	BL	TANK 2
00	8/29	H105 + W106	H5 + H6	Mixed	BL	TANK 3
00	9/05	H202	W1 + H19	Mixed	BL	TANK 4
00	9/05	H203 + H204	W2 + H7	Mixed	BL	TANK 5
00	9/05	H205 + H206	H8 + H9	Hatchery	BL	TANK 6
00	9/05	H209 + H210	H12 + H13	Hatchery	BL	TANK 7
00	9/05	H211	H14 + H15	Hatchery	BL	TANK 8
00	9/05	H213 + H214	H16 + H17	Hatchery	BL	TANK 9
00	9/05	W215	H10 + H11	Mixed	BL	TANK 10
00	9/12	H301 + H302	H20 + H24	Hatchery	BL	TANK 11
00	9/12	H303 + H304	W3 + H23	Mixed	BL	TANK 12
00	9/12	H308 + H311	W5 + H22	Mixed	BL	TANK 13
00	9/19	W401 + H402	H30 + H31	Mixed	BL	TANK 14
00	9/19	H403 + H404	W6 + H32	Mixed	BL	TANK 15

[1] Low = 0.11-0.19 Optical Density; Below Low = < 0.11 Optical Density.

Table 3. Selection of progeny for the Tucannon River spring Chinook captive broodstock program based on origin, crosses, and BKD ELISA results, 2001 and 2002 (for extra males) BYs.

Brood Year	Eggtake Date	Female Numbers	Male Numbers	Crosses	BKD ELISA[1]	Tank/Family Number
01	8/28	H101 + H103	28A2 + BCCC	Mixed	BL	TANK 1
01	9/04	W201 + W203	HM8 + HM9	Mixed	BL	TANK 2
01	9/04	W205 + W207	HM4 + HM5	Mixed	BL	TANK 3
01	9/04	H206 + H208	B2F4 + AAE7	Mixed	BL	TANK 4
01	9/04	W211 + W212	HM3 + HM6	Mixed	BL	TANK 5
01	9/04	H210 + H213	AOFB + DB6E	Mixed	BL	TANK 6
01	9/04	W214 + W220	HM2 + HM7	Mixed	BL	TANK 7
01	9/11	W301 + W303	HM10 + HM11	Mixed	BL	TANK 8
01	9/11	W314	HM16 + HM23	Mixed	BL	TANK 9
01	9/11	W304 + W305	HM12 + HM14	Mixed	BL	TANK 10
01	9/11	W307 + W308	HM13 + HM17	Mixed	BL	TANK 11
01	9/11	H309 + H311	9890 + 2912	Mixed	BL	TANK 12
01	9/11	H312	FEAC + 5F6F	Mixed	BL	TANK 13
01	9/18	W401 + W409	HM25 + HM26	Mixed	BL	TANK 14
01	9/18	W410 + W411	2626 + AF96	Natural	BL	TANK 15
02	8/27	W103 + W104	HM1 + HM2	Mixed	BL	TANK 1
02	8/27	H110	D0AA + AB01	Mixed	BL	TANK 2
02	9/03	W203 + W204	HM5 + HM6	Mixed	BL/LOW	TANK 3
02	9/03	W211 + W215	HM7 + HM8	Mixed	BL	TANK 4
02	9/03	W217 + W219	HM9 + HM10	Mixed	BL	TANK 5
02	9/03	H209 + H210	B5BD + 8D07	Mixed	BL	TANK 6
02	9/03	H212 + H213	A6CE + BC25	Mixed	BL	TANK 7
02	9/03	H214 + H216	A0CD + 29BC	Mixed	BL	TANK 8
02	9/10	W301 + W303	HM11 + HM12	Mixed	BL	TANK 9
02	9/10	W307 + W309	HM15 + HM16	Mixed	BL/LOW	TANK 10
02	9/17	H401 + H402	1515 + 98BA	Mixed	BL	TANK 11
02	9/17	H403 + H404	C045 + BF27	Mixed	BL	TANK 12
02	9/17	H405 + H408	A58C + BEB0	Mixed	BL	TANK 13
02	9/17	W406 + W407	HM24 + HM25	Mixed	BL	TANK 14
02	9/17	W409 + W410	HM19 + HM20	Mixed	LOW/BL	TANK 15

[1] Low = 0.11-0.19 Optical Density; Below Low = < 0.11 Optical Density.

APPENDIX B

Average length (mm), weight (g), and condition factor (K) with standard deviations for each family unit from the 1997, 1998, 1999, 2000 and 2001 BYs of captives at the time of tagging.							
Brood Year	Family Unit	Number of Fish	Mean Length	S.D.	Mean Weight	S.D.	K
1997	1	29	113	7.8	19.4	4.4	1.31
1997	2	14	110	5.2	17.3	2.7	1.29
1997	3	31	125	9.1	28.4	6.0	1.44
1997	4	29	118	9.3	22.7	6.0	1.37
1997	5	31	119	9.3	22.7	5.8	1.30
1997	6	30	119	8.6	22.6	5.2	1.33
1997	7	30	117	7.2	21.3	4.3	1.32
1997	8	29	121	10.2	24.8	6.8	1.36
1997	9	30	117	8.1	21.8	5.0	1.32
1997	10	30	115	11.0	19.7	6.1	1.27
1997	11	30	101	6.4	13.1	2.6	1.25
1997	12	30	120	12.5	24.5	8.0	1.38
1997	13	30	121	9.3	24.4	6.6	1.34
1997	14	30	112	6.2	18.8	3.2	1.33
1997	15	30	109	9.6	18.7	4.8	1.41
Totals / Means		**433**	**116**	**10.5**	**21.5**	**6.4**	**1.34**
1998	1	30	120	15.6	22.3	8.6	1.23
1998	2	29	108	10.0	15.9	5.0	1.25
1998	3	30	112	13.1	18.6	7.8	1.26
1998	4	30	112	11.5	17.7	6.4	1.24
1998	5	30	117	16.0	20.5	9.9	1.20
1998	6	28	117	15.0	21.6	11.0	1.26
1998	7	32	120	18.0	23.2	11.6	1.26
1998	8	30	129	12.0	26.5	7.8	1.21
1998	9	30	121	16.9	23.0	9.9	1.24
1998	10	28	130	9.0	26.0	4.9	1.18
1998	11	25	120	13.6	22.3	7.7	1.26
1998	12	31	127	10.1	24.0	4.9	1.16
1998	13	29	122	11.4	22.0	6.7	1.19
1998	14	27	120	13.2	21.6	7.7	1.20
1998	15	29	138	11.0	30.3	6.7	1.14
Totals / Means		**438**	**121**	**15.2**	**22.4**	**8.7**	**1.22**
1999	1	27	147	14.6	41.1	11.3	1.25
1999	2	28	138	13.1	35.7	8.9	1.34
1999	3	28	133	11.6	33.9	11.3	1.42
1999	4	30	145	8.9	39.2	6.7	1.27
1999	5	25	136	15.8	35.4	11.8	1.34
1999	6	30	136	10.7	33.8	8.9	1.32
1999	7	27	129	20.9	30.0	14.8	1.29
1999	8	29	129	12.0	29.9	9.0	1.35
1999	9	25	128	16.3	29.3	11.6	1.33
1999	10	23	130	18.9	31.0	14.4	1.32
1999	11	23	137	13.1	36.0	10.7	1.37
1999	12	28	141	13.5	38.4	10.2	1.33
1999	13	30	133	13.9	31.9	9.1	1.34
1999	14	30	133	10.7	31.6	7.6	1.32
1999	15	26	132	16.6	34.1	14.1	1.39
Totals / Means		**409**	**135**	**15.1**	**34.1**	**11.2**	**1.33**

Appendix B (cont.). Average length (mm), weight (g), and condition factor (K) with standard deviations for each family unit from the 1997, 1998, 1999, 2000 and 2001 BYs of captives at the time of tagging.

Brood Year	Family Unit	Number of Fish	Mean Length	S.D.	Mean Weight	S.D.	K
2000	1	30	164	11.8	52.3	8.4	1.19
2000	2	30	157	11.1	45.5	8.1	1.16
2000	3	30	152	10.1	37.9	5.9	1.08
2000	4	30	152	11.0	43.0	8.0	1.20
2000	5	30	152	8.4	38.6	5.9	1.09
2000	6	30	138	11.3	31.2	6.1	1.18
2000	7	30	140	10.1	31.4	5.4	1.14
2000	8	30	147	8.4	35.0	5.4	1.10
2000	9	30	151	9.5	37.3	6.3	1.07
2000	10	30	151	7.7	37.4	5.7	1.08
2000	11	30	143	13.9	34.9	8.3	1.18
2000	12	30	147	9.1	35.4	5.2	1.12
2000	13	30	144	13.5	34.1	8.7	1.13
2000	14	30	136	9.4	27.1	4.5	1.08
2000	15	30	132	10.8	25.1	5.1	1.10
Totals / Means		**450**	**147**	**13.4**	**36.4**	**9.4**	**1.13**

2001	1	30	95	6.7	10.4	2.1	1.22
2001	2	30	101	8.7	12.6	3.0	1.22
2001	3	30	100	5.0	12.8	1.9	1.27
2001	4	30	107	6.9	14.8	3.9	1.21
2001	5	30	110	8.3	17.5	3.2	1.30
2001	6	30	104	7.7	14.7	3.6	1.29
2001	7	30	101	6.9	13.1	2.4	1.27
2001	8	30	105	8.2	14.6	2.6	1.25
2001	9	30	106	9.2	13.8	3.1	1.17
2001	10	30	97	6.5	11.4	2.4	1.24
2001	11	30	101	7.5	12.7	2.7	1.21
2001	12	30	101	5.0	12.5	1.8	1.21
2001	13	30	100	7.5	12.2	2.9	1.20
2001	14	30	100	8.8	12.2	2.9	1.22
2001	15	30	99	7.6	12.2	2.7	1.25
Totals / Means		**450**	**102**	**8.3**	**13.2**	**3.2**	**1.24**

APPENDIX C

Appendix C, Table 1. Tucannon River spring Chinook captive broodstock mortalities by family unit, sex, age, and maturity for the 1997 brood year.

		Males											Females												
		Age 1	Age 2		Age 3			Age 4			Age 5		Age 1	Age 2	Age 3			Age 4			Age 5				
Family Unit	N	IM	IM	MA	IM	MA	SP	IM	MA	SP	MA	SP	IM	IM	IM	MA	SP	IM	MA	SP	IM	MA	SP	Total Mort.[1]	% Mort.[2]
1	29		1	4		6				1				3					3	9		1	1	29	100
2	14			4		1	2													6				13	93
3	31		3	4		3					1		1		1			1	3	6		2	2	27	87
4	29		2	4		10				1				3			1			9				30	103
5	31			8		7	1			2				4	1					7	1			31	100
6	30		2	13		1		1						3	1	1		1	2	7			1	33	110
7	30		1	5		5	1			2				3				1		9			3	30	100
8	29			14		1								1	1		2			9				28	97
9	30		2	6		5	2							4						12				31	103
10	30		1	7		5				2				3	1		3		2	7				31	103
11	30	1	2	3		6	1		2					3					1	12				31	103
12	30		2	5		4				1		1		3			4			10				30	100
13	30		1	7		4								1	1					11			2	27	90
14	30		1	1	1	13	1			1					1		1			7	1	1	1	30	100
15	30		1	7		2			1	1				7			1		2	5				27	90
Totals	433	1	19	92	1	73	8	1	3	11	1	1	1	38	7	1	12	3	13	126	2	4	10	431	99

IM = Immature, MA = Mature, SP = Spawned
[1]Total includes 3 fish of unknown sex.
[2]Some percentages higher than 100% due to misreading of visible implant tags.

Appendix C, Table 2. Tucannon River spring Chinook captive broodstock mortalities by family unit, sex, age, and maturity for the 1998 brood year.

Family Unit	N	Males Age 1 IM	Males Age 2 IM	Males Age 2 MA	Males Age 3 IM	Males Age 3 MA	Males Age 3 SP	Males Age 4 IM	Males Age 4 MA	Males Age 4 SP	Males Age 5 MA	Males Age 5 SP	Females Age 1 IM	Females Age 2 IM	Females Age 2 MA	Females Age 3 IM	Females Age 3 MA	Females Age 3 SP	Females Age 4 IM	Females Age 4 MA	Females Age 4 SP	Females Age 5 IM	Females Age 5 MA	Females Age 5 SP	Total Mort.[1]	% Mort.[2]
1	30			12		1			1	1								1	2	2	8			1	29	97
2	29			9			6			1										1	8				25	86
3	30			11			1						1	2				2		1	8			1	27	90
4	30		1	10		1	6		1					2				1			9				31	103
5	30			8			5			1				1				4		2	6				27	90
6	28		2	5			6			2								2			9				26	93
7	32		1	8			7					1						2			8			1	28	88
8	30		1	9			7										1	1		2	6				27	90
9	30			5		1	3			1				1		1		2		7	6				27	90
10	28			15						1							1	9			3				29	104
11	25			10	2		1											6		1	3				23	92
12	31	1		11			3			1			1					7	1		6				31	100
13	29		1	8		1	6										1			1	6	1	1	1	27	93
14	27		1	10			1									1		1		4	6			1	25	93
15	29	3		11			1						4					4		1	2				26	90
Totals	438	4	7	142	2	4	53		2	8		1	6	6		2	3	42	3	22	94	1	1	5	437	99.8

IM = Immature, MA = Mature, SP = Spawned

[1]Total includes 8 fish of unknown sex and 21 adult outplants.

[2]Some percentages higher than 100% due to misreading of visible implant tags.

Appendix C, Table 3. Tucannon River spring Chinook captive broodstock mortalities by family unit, sex, age, and maturity for the 1999 brood year.

Family Unit	N	Males												Females											Total Mort.[1]	% Mort.
		Age 1	Age 2			Age 3			Age 4			Age 5		Age 1	Age 2	Age 3			Age 4			Age 5				
		IM	IM	MA	SP	IM	MA	SP	IM	MA	SP	IM	SP	IM	IM	IM	MA	SP	IM	MA	SP	IM	MA	SP		
1	27			6	3		1											1			10				21	78
2	28		1	6	1			2			2							4			8			1	25	89
3	28			4	2			5			1						1				13				26	93
4	30		1	3				4					1				2	1			8			1	21	70
5	25			3	4			2										2		1	11				23	92
6	30			5	2	1		2										1		1	9	1		2	24	80
7	27			5				2	1		1									1	6			4	20	74
8	29			3	2			1			1	1					1	1	1		11			1	23	79
9	25			5	2			1	1									1			11				21	84
10	23			4	1			1			1						1	1		1	11				21	91
11	23			4	1			1													11			1	18	78
12	28			4				1										1			12				18	64
13	30	1		7	1												1	4		1	13				28	93
14	30			5				3					1							1	15			2	27	90
15	26			1	1			1								2		1	1		9	1			17	65
Totals	409	1	2	65	20	1	1	26	2		6	1	2			2	6	18	2	6	158	2		12	409	100

IM = Immature, MA = Mature, SP = Spawned
[1]Total includes 76 adult outplants.

Appendix C, Table 4. Tucannon River spring Chinook captive broodstock mortalities by family unit, sex, age, and maturity for the 2000 brood year.

Family Unit	N	Males												Females												Total Mort.	% Mort.[1]
		Age 1	Age 2			Age 3			Age 4			Age 5		Age 1	Age 2		Age 3			Age 4			Age 5				
		IM	IM	MA	SP	IM	MA	SP	IM	MA	SP	MA	SP	IM	IM	MA	IM	MA	SP	IM	MA	SP	IM	MA	SP		
1	30	1		2	3														8			15				29	97
2	30			4	3			3											1			19				30	100
3	30			1	3			7			1	1							1	1		15				30	100
4	30			6	5		1				1			1	1				4	1		10		1		31	103
5	30			3	8	1		2											2	1		12				29	97
6	30			3	2	1	1	10	1										1			11				30	100
7	30			3	1			11							1				1			15				32	107
8	30			4	2			2							1				16			4				29	97
9	30			2	6		1	9											4			8				30	100
10	30			3	3			9											1			14				30	100
11	30			7				2											4	1	1	13		1		29	97
12	30			2	5		1	3									1	1	11			5				29	97
13	30		1	5	2			8											3	1		8				28	93
14	30			7	4			5							1				1		1	11				30	100
15	30		1					10									1		2		1	14		1		30	100
Totals	450	1	2	52	47	2	4	81	1		2	1		1	4		2	1	60	5	3	174		3		446	99

IM = Immature, MA = Mature, SP = Spawned

[1]Some percentages higher than 100% due to misreading of visible implant tags.

Appendix C, Table 5. Tucannon River spring Chinook captive broodstock mortalities by family unit, sex, age, and maturity for the 2001 brood year.

		Males												Females													
		Age 1	Age 2			Age 3			Age 4			Age 5		Age 1	Age 2		Age 3			Age 4			Age 5				
Family Unit	N	IM	IM	MA	SP	IM	MA	SP	IM	MA	SP	IM	MA	IM	IM	MA	IM	MA	SP	IM	MA	SP	IM	MA	SP	Total Mort.	% Mort.
1	30				2			13									1		1		2	7			1	27	90
2[a]	30							8	1				1						4		3	7		1		28[a]	93
3	30		1		1			13									1		2	1	2	8			1	30	100
4	30		1		3			6							2				1	2	1	13				29	97
5	30				3			11									1		1	1	2	11				30	100
6[b]	30							12									1		2		2	11				29[b]	97
7	30		1			1		9		1					1				3	1	2	10				29	97
8	30				1			14											1	1	2	10	1			30	100
9	30				8			9											5		3	4				29	97
10	30				7			4									1		1		2	10	2		1	28	93
11	30				3		2	11											3		1	7				27	90
12	30				4			12			1	1							1		1	8	1			29	97
13	30							12	2										1		3	5			3	26	87
14	30				1		1	11							1					1	2	12			2	31	103
15	30		1		2	1		14									1		4		1	5				29	97
Totals	450		4		35	2	3	159	3	1	1	1	1		4		6		30	7	29	135[c]	4	1	8	438[c]	97

IM = Immature, MA = Mature, SP = Spawned

[a] Total includes 3 fish of unknown sex. (Three died from family 2 during tagging).

[b] Total includes 1 fish of unknown sex (just fish head found from Age 2).

[c] Total includes 7 fish from unknown families.

APPENDIX D

Appendix D. Movements of ten radio tagged captive female adults released into the Tucannon River during 2002.			
Channel/Code Date	**Tucannon rkm**	**Location**	**Comments**
9/165			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 58.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	72.0	3rd Cattle guard	
8/30/02	73.0	100 m above C.C. Br.	
9/05/02	73.0	100 m above C.C. Br.	Drive by.
9/09/02	72.8	Below C.C. Bridge	Between campground and cattle guard.
9/13/02	72.9	Below C.C. Bridge	R.B. lower end of habitat site, by new redd.
9/16/02	72.9	Below C.C. Bridge	L.B. below rocks, with natural male.
9/20/02	72.9	Below C.C. Bridge	Area where she was digging now small T.D.
9/23/02	72.9	Below C.C. Bridge	Fungused eyes, fins, tail frayed.
9/25/02	72.9	Below C.C. Bridge	Recovered tag and fish, 100% spent.
9/167			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 55.5 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	73.2	HMA5-S Side Channel	
8/30/02	73.3	Log jam below log weir	
9/05/02	72.9	Cow Camp Bridge	Drive by.
9/09/02	73.0	100 m above C.C. Br.	By redd 2-6, with other fish, natural male close by.
9/13/02	73.0	100 m above C.C. Br.	Recovered tag and fish – did not spawn.
9/171			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 56.5 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	73.2	HMA5-S Side Channel	
8/30/02	73.2	HMA5-S Side Channel	
9/05/02	73.2	Between C.C. and C.G. 9	Drive by.
9/09/02	73.4	Above C.C. Br. - .35 km	Log jam near 9/04/02JD test dig.
9/13/02	74.5	Below Panjab Ck. Mouth	Went down to pool with 9/183 then upstream.
9/16/02	73.6	C.G. 9 lower entrance	Drive by.
9/20/02	73.6	S.C. at C.G. 9	Near new redds in S.C., not actively digging.
9/23/02	73.4	Log jam above rock sill	Recovered tag and fish. Fish partially eaten.
9/179			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 55.5 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02		Ladybug Flat?	Couldn't locate – heard chirps near Ladybug.
8/30/02		Not Found	Couldn't locate.
9/05-9/02	77.7	Ladybug Flat	Run and pool under poplar, fish moving around.
9/13-16/02	77.7	Ladybug Flat	Under alder, about 25 m upstream of path sign.
9/20/02	77.7	Ladybug Flat	Recovered tag only. Tag found between rocks. Possibly poached.

Appendix D (continued). Movements of ten radio tagged captive female adults released into the Tucannon River during 2002.

Channel/Code Date	Tucannon rkm	Location	Comments
9/183			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 52.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	74.4	Below Panjab Bridge	
8/30/02	74.5	Panjab Bridge	
9/05/02	74.5	Above Panjab Bridge	In 2nd pool above bridge.
9/09/02	74.5	Above Panjab Bridge	In 2nd pool above bridge.
9/13/02	74.5	Above Panjab Bridge	In 2nd pool above bridge.
9/16/02	74.5	Above Panjab Bridge	Drive by.
9/20/02	74.5	Above Panjab Bridge	Recovered tag only on bank – possibly poached.
9/184			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 51.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	74.5	Panjab Bridge	
8/30/02	74.6	Wilderness C.G. 1	
9/05/02	74.6	Info. sign below C.G. 1	Below redd 3-7MH, saw fish.
9/09/02	72.9	Below Cow Camp Bridge	Upper end of camping area.
9/13/02	69.0	Below Cattle Chute Area	Drive by.
9/16/02	69.0	Below Cattle Chute Area	Fish fungused – will not live long.
9/20/02	68.7	Above Camp Wooten Cabins	In log jam at lower end of side channel.
9/23/02	68.7	HMA 15 – Above Cabins	Drive by.
9/192			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 50.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02		Ladybug?	Couldn't locate – heard chirps near Ladybug.
8/30/02	74.4	Below Panjab Bridge	
9/05/02	74.7	Wild C.G. 1	Saw fish in pool across from 2 week old redd.
9/09/02	74.5	100 m below main info. sign	Wood cutting area sign.
9/13/02	74.6	Below C.G. 1	Beside redd 4-4, not on redd though.
9/16/02	73.7	C.G. 9	Drive by.
9/20/02	73.6	S.C. at C.G. 9	Near new redds in S.C., not actively digging.
9/23/02	73.6	S.C. at C.G. 9	Near redd 5-3 (9-18-02JD).
9/27/02	73.6	Below C.G. 9	Recovered tag and fish – 100% spawned.
9/193			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 51.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	72.0	3rd Cattle Guard	
8/30/02	73.0	100 m above C.C. Bridge	
9/05/02	73.5	Lower end C.G. 9	Couldn't pinpoint – tag may be out of fish.
9/09/02	73.5	Across from house, above C.C.	In run 10 m above National Forest Boundary.
9/13/02	73.5	Across from house, above C.C.	Tag in otter den.
9/23/02	73.5	Across from house, above C.C.	Tag in den.

Appendix D (continued). Movements of ten radio tagged captive female adults released into the Tucannon River during 2002.

Channel/Code Date	Tucannon rkm	Location	Comments
9/203			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 49.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	74.5	Panjab Bridge	
8/30/02		Not Found	Lost contact.
9/05/02		Not Found	Lost contact.
9/205			
7/16/02		Lyons Ferry Hatchery	Length at tagging – 47.0 cm.
8/20/02	74.5	Panjab Bridge	Released into river.
8/27/02	74.4	Below Panjab Bridge	
8/30/02		Not Found	
9/05/02	76.6	1 km below Ladybug Flat	Fish holding under spruce over river.
9/09/02	76.6	1 km below Ladybug Flat	50 m downstream of road 025.
9/13/02	76.6	1 km below Ladybug Flat	Recovered tag only under brush on bank. Possibly poached.

APPENDIX E

Summary of captive brood progeny releases from the Tucannon River spring Chinook captive broodstock program.								
Release Year	**BY[1]**	**Release Date**	**CWT**	**No Wire**	**Wire**	**Total Released**	**Lbs**	**Fish/Lb**
2002	2000 (S)	3/15-4/23	63	24	3,031	3,055	343	8.9
2002	2001 (P)	5/06	63/14/30	157	20,435	20,592	124.8	165.0
2003	2001 (S)	4/01-4/21	63	5,995	134,401	140,396	10,100	13.9
2004	2002 (S)	4/01-4/20	63	1,909	42,875	44,784	3,393	13.2
2005	2003 (S)	3/28-4/15	63/27/78	4,760	125,304	130,064	9,706	13.4
2006	2004 (S)	4/03-4/26	63/28/65	5,150	127,162	132,312	8,648	15.3
2007	2005 (S)	4/02-4/23	63/34/77	1,171	88,885	90,056	12,170	7.4
2008	2006 (S)	4/08-4/22	63/41/94	2,893	75,283	78,176	9,896	7.9

[1] S = Smolt release; P = Parr release.

APPENDIX F

Appendix F. Cumulative detection (one unique detection per tag code) and travel time (TD) summaries of PIT tagged conventional hatchery and captive brood origin Tucannon River spring Chinook salmon released from Curl Lake Acclimation Pond (rkm 65.6) on the Tucannon River at downstream Snake and Columbia River dams for the 2001-2006 brood years. (Fish were volitionally released).

		Release Data			Recapture Data											
Brood			Mean		Mean	LMJ		MCJ		JDJ		BONN		Total[a]	
Year	Origin	N	Length	S.D.	Length	N	TD	N	TD	N	TD	N	TD	N	%
2001	Hatch.	1,010	125.5	19.5	124.3	119	13.5	178	18.6	53	25.0	23	24.4	373	36.9
2001	C.B.	1,007	116.5	14.8	117.5	101	12.1	134	18.3	37	24.0	13	24.2	285	28.3
2002	Hatch.	1,012	136.8	16.9	139.0	44	9.6	108	12.1	34	18.3	7	16.1	193	19.1
2002	C.B.	1,029	125.5	16.6	128.9	41	10.4	106	12.4	41	17.6	6	17.1	194	18.9
2003	Hatch.	993	119.8	13.2	121.3	165	24.4	85	30.8	30	33.6	5	35.8	285	28.7
2003	C.B.	993	123.8	16.1	127.1	142	21.8	65	30.9	28	33.3	9	39.4	244	24.6
2004	Hatch.	1,001	128.0	13.1	128.3	136	13.6	97	16.1	40	21.2	18	22.5	327	32.7
2004	C.B.	1,002	125.3	14.6	127.0	127	12.4	87	16.7	30	22.7	14	18.6	279	27.8
2005	Hatch.	1,002	134.3	15.8	134.5	138	20.8	131	24.2	126	28.5	26	30.3	467	46.6
2005	C.B.	1,000	135.1	19.6	135.4	88	22.0	135	25.0	109	28.7	34	30.4	413	41.3
2006	Hatch.	2,498	149.6	20.9	148.4	271	31.4	198	33.8	111	39.0	21	38.5	782	31.3
2006	C.B.	997	---	---	---	82	29.9	78	34.1	35	35.7	6	43.7	265	26.6

[a] Total includes detections at Ice Harbor Dam.

Note: Mean travel times listed are from total number of fish detected at each dam, not unique recoveries for a tag code.

Abbreviations are as follows: LMJ – Lower Monumental Dam; MCJ – McNary Dam; JDJ – John Day Dam; BONN – Bonneville Dam; S.D. – Standard Deviation; TD – Mean Travel Days.

APPENDIX G

Appendix F. Estimates of captive, conventional hatchery, and natural origin Tucannon spring Chinook salmon abundance by life stage for the 2000-2006 brood years.

Brood Year	Females Spawned	Mean Fecundity[a]	Number of Eggs	Number of Parr	Number of Smolts	Number of Spawners	Progeny (Returning Adults)
Captive							
2000	12	1,298	14,577	4,323	3,055	25	0
2001	166	1,765	281,303	195,264	140,396	272	17
2002	121	1,561	176,544	50,462	44,784	234	2
2003	223	1,389	309,416	164,800	130,064	375	21
2004	205	1,549	310,819	140,874	132,312	364	82[b]
2005	167	1,595	261,845	93,971	90,056	247	158[b]
2006	86	1,892	162,736	79,432	78,176	127	0[b]
Conventional Hatchery							
2000	38	3,345	128,980	123,313	102,099	73	157
2001	56	3,252	184,127	174,934	146,922	104	125
2002	47	3,368	169,364	151,531	123,586	93	120
2003	37	3,812	140,658	126,400	71,154	75	71
2004	46	2,601	140,459	128,877	67,542	88	116[b]
2005	49	2,903	161,345	151,466	149,466	95	291[b]
2006	45	2,654	123,629	112,350	106,530	88	0[b]
Natural							
2000	92	3,969	323,964	44,618	20,045	239	446
2001	298	3,612	1,047,936	63,412	38,079	894	244
2002	299	3,981	1,070,784	72,197	60,530	897	202
2003	118	3,789	448,275	40,900	23,003	366	173
2004	160	3,444	514,791	30,809	21,057	480	360[b]
2005	102	3,773	363,096	21,162	17,579	317	131[b]
2006	101	2,887	283,199	---[c]	30,228	161	0[b]

[a] Based on fully spawned females.
[b] Incomplete brood year – adults still returning.
[c] Snorkel surveys not conducted.