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Yakima/Klickitat Fisheries Project: Short Project Overview of Spring Chinook Salmon Supplementation in the Upper Yakima Basin

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Spring Chinook Salmon Supplementation in the Upper Yakima Basin: Yakima/Klickitat Fisheries Project Overview

Annual Report 2004-2005

Performance Period: August, 2004 – July, 2005

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This report is an overview of the work conducted on spring chinook salmon as part of the Yakima/Klickitat Fisheries Project (YKFP). The purpose of this document is to synthesize the available information that has already been provided in lengthy topical reports into an easy to read synthesis of the project. In this way, we hope that the scope and progress of the YKFP can be fully appreciated. The YKFP is still in the early stages of evaluation, and as such the data and findings presented in this report should be considered preliminary until further data is collected and analyses completed. We encourage the reader to consult the topical reports for detailed descriptions of particular topics. References to these reports are provided at the end of this document. There are also other components of the YKFP that address coho and fall chinook salmon. Those components are not addressed in this report.

The YKFP is funded under BPA contracts to the Yakama Nation and the Washington Department of Fish and Wildlife. The following contracts provided the support to complete the work that is the basis for this report.

Policy/Technical Involvement and Planning in the Yakima/Klickitat Fisheries Project; Project Number 1995-064-25; Contract 00018827 - WDFW

Yakima/Klickitat Fisheries Project's Monitoring and Evaluation; Project Number 1995-063-25; Contract 00017478 – WDFW

Yakima/Klickitat Fisheries Project's Monitoring and Evaluation; Project Number 1995-063-25; Contract 00017635 – Yakama Nation

Yakima/Klickitat Fisheries Project's Management, Data, and Habitat; Project Number 1988-120-25; Contract 00017274 – Yakama Nation

Executive Summary

The Yakima/Klickitat Fisheries Project (YKFP) is on schedule to ascertain whether new artificial production techniques can be used to increase harvest and natural production of spring Chinook salmon 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 Cle Elum Supplementation and Research Facility (CESRF) collected its first spring chinook brood stock in 1997, released its first fish in 1999, and age-4 adults have been returning since 2001. In these initial years of CESRF operation, recruitment of hatchery origin fish has exceeded that of fish spawning in the natural environment, but early indications are that hatchery origin fish are not as successful at spawning in the natural environment as natural origin fish when competition is relatively high. When competition is reduced, hatchery fish produced similar numbers of progeny as their wild counterparts. Most demographic variables are similar between natural and hatchery origin fish, however hatchery origin fish were smaller-at-age than natural origin fish. Long-term fitness of the target population is being evaluated by a large-scale test of domestication. Slight changes in predation vulnerability and competitive dominance, caused by domestication, were documented. Distribution of spawners has increased as a result of acclimation site location and salmon homing fidelity. Semi-natural rearing and predator avoidance training have not resulted in significant increases in survival of hatchery fish. However, growth manipulations in the hatchery appear to be reducing the number of precocious males produced by the YKFP and consequently increasing the number of migrants. Genetic impacts to non-target populations appear to be low because of the low stray rates of YKFP fish. Ecological impacts to valued non-target taxa were within containment objectives or impacts that were outside of containment objectives were not caused by supplementation activities. Some fish and bird piscivores have been estimated to consume large numbers of salmonids in the Yakima Basin. Natural production of Chinook salmon in the upper Yakima Basin appears to be density dependent under current conditions and may constrain the benefits of supplementation. However, such constraints (if they exist) could be countered by YKFP habitat actions that have resulted in: the protection of over 900 acres of prime floodplain habitat, reconnection and screening of over 15 miles of tributary habitat, substantial water savings through irrigation improvements, and restoration of over 80 acres of floodplain and side channels. Harvest opportunities for tribal and non-tribal fishers have also been enhanced, but are variable among years. The YKFP is still in the early stages of evaluation, and as such the data and findings presented in this report should be considered preliminary until further data is collected and analyses completed. Nonetheless, the YKFP has produced significant findings, and produced methodologies that can be used to evaluate and improve supplementation. A summary table of topical area performance is presented below.

Table 1. Performance of the Yakima Fisheries Project relative to topical performance measures.

Performance Measure	Goal	Performance	Comments
Natural Production of Target Species	Increase while maintaining the long-term fitness of the target population	Unknown – but indications of both encouragement and concern	- Too early to evaluate conclusively, but strategies to reduce genetic risk are being implemented. - Hatchery has increased the number and distribution of adult spawners on the spawning grounds. - Reproductive success and domestication experiments suggest some cause for concern. - Predation and competition may be limiting natural production objectives and may constrain the benefits of supplementation.
Harvest	Increase	Increased, but variable to date	Significant tribal subsistence fisheries occurred on both hatchery and naturally produced fish. Significant sport fisheries on hatchery fish have also occurred in the Yakima River since 2001 with the exception of 2003 and 2005 when returns were significantly reduced due to poor juvenile outmigration conditions for this brood and/or poor ocean conditions.
Genetics	Minimize genetic impacts to non-target taxa	Achieved to date	Stray rates are very low
Ecology	Keep impacts to non-target taxa within containment objectives	Achieved to date	Impacts are within containment objectives or are currently not attributable to supplementation.

Table 1. (continued)
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Performance Measure	Goal	Performance	Comments
Habitat	Protect the most productive stream reaches and increase productivity/capacity of freshwater environment	Progress	BPA's temporary hold on habitat purchases has delayed protection efforts. Tributary passage efforts and habitat restoration are ongoing, with incremental progress each year. - Habitat actions should enhance the benefits of supplementation, especially over the long-term.
Science	Disseminate important findings for use throughout the Yakima Basin, Columbia Basin, and world	Achieved to date	Numerous annual reports were submitted to BPA, all tasks were reported on at annual conferences, and manuscripts have been prepared and published. The effects of mass marking and selective fisheries could confound evaluation of adult survival differences between wild/natural and supplementation/hatchery fish.

Short Project Overview

Salmon and steelhead populations in the Yakima Basin and throughout the Columbia Basin are far below historic levels. For example, an average of 200,000 spring chinook salmon returned to the Yakima Basin prior to 1800, but declined to an average of fewer than 3,500 fish annually from 1982-1999. Hatcheries have been used as the primary tool to mitigate for the losses of salmon in the Columbia Basin. However, naturally produced salmon have continued to decline despite large releases of hatchery fish. This decline in abundance has caused many Evolutionary Significant Units of salmon and steelhead to be listed for federal protection under the Endangered Species Act. Traditional hatchery operations have been successful at producing fish for harvest, but may actually harm naturally produced fish through ecological, genetic, facility, and harvest interactions.

The YKFP is designed to determine whether it is possible to change hatchery practices so that adjacent natural spawning populations of salmon receive biological benefits from a hatchery program. The project is also examining whether these same hatchery practices can be managed to limit deleterious impacts on non-enhanced fish populations. More specifically, the YKFP is testing whether "artificial propagation [can be used] to increase natural production while maintaining the long term fitness of the target population, and keeping the ecological and genetic impacts on non-target populations within specified biological limits" (RASP 1992). In addition, increasing harvest opportunities for tribal and non-tribal fishers is also part of the overall goal. In short, the YKFP is attempting to quantify the ecological and genetic benefits and costs of supplementation.

In order to test whether supplementation works, in the Yakima Basin or elsewhere, at least four major questions must be answered:

1) Can integrated hatchery programs be used to increase long-term natural production?
2) Can integrated hatchery programs limit genetic impacts to non-target chinook populations?
3) Can integrated hatchery programs limit ecological impacts to non-target populations?
4) Does supplementation increase harvest opportunities?

These major questions are very difficult to answer and require large amounts of time, significant physical infrastructure, qualified staff, and environments that are amenable to sampling. It is estimated that evaluations of these questions could take between 8 and 30 years (Table 2). Permanent counting and collection facilities (e.g., Roza Dam Adult Counting Facility, Chandler Bypass Juvenile Facility), highly adaptable and monitorable hatchery facilities (Cle Elum Supplementation and Research Facility and three acclimation facilities), an experimental spawning channel (at CESRF), and diverse field and sampling equipment (e.g., electrofishers, boats, tagging trailers) are some parts of the infrastructure that are necessary. The YKFP is also staffed by scientists that are experts in fields such as genetics, ecology, reproductive behavior, population dynamics, fish culture, sampling methods, statistics, and database management. Based on decades of earlier work in the Yakima Basin, we know what types of sampling are feasible and what sample sizes are needed to achieve an appropriate statistical power.

Table 2. Important milestones of the YKFP.

Year	Milestones
1982-1999	Significant amount of baseline data collected
1997	First adult fish taken for broodstock at Roza Dam and transferred to CESRF
1999	First CESRF smolts released from acclimation sites
2000	First CESRF jacks return and spawn in the river, first adults placed into experimental spawning channel
2001	First CESRF age 4 fish return and spawn in the river
2002	Hatchery control line initiated (hatchery x hatchery cross)
2004	Wild control line initiated (Naches Basin wild x wild cross)
2004	First hatchery control line smolts released
2005	First age-4 returns from supplementation and wild fish spawning in the river
2005	First hatchery control line jacks return
2006	First hatchery control line age 4 fish return

With a project of this magnitude, there are many management decisions that are made that integrate and balance stewardship, utilization, legal, and scientific values. The Yakama Nation and Washington Department of Fish and Wildlife are responsible for co-managing the natural resources in the Yakima Basin. Policy representatives of these two agencies interact regularly with technical representatives to forge sound management decisions that guide the YKFP. Management decisions are made within the frameworks of adaptive management and risk management.

This report updates findings though July 31, 2005 and is structured around the four critical questions about supplementation.

1. Can integrated hatchery programs be used to increase natural production?

For supplementation to be successful, the number of adult “grandchildren” (natural origin recruits, F2) produced from parents that spent one generation in the hatchery must be larger than the number of adult grandchildren from parents spawning exclusively in the natural environment. In other words, the product of the hatchery recruitment rate and the recruitment rate of hatchery fish spawning in the wild must be greater than the recruitment rate of fish spawning in the natural environment for two consecutive generations.

During the first generation (F1), the recruitment rate for hatchery fish must exceed that of fish spawning in the natural environment. In order for this to occur, fish taken into the hatchery must have high survival in the hatchery and they must survive well after they are released into the natural environment. In short, these fish must survive well in both hatchery and natural environments and reproduce well in hatchery environments. To increase the probability of success, the CESRF employs best hatchery practices such as: using broodstock that are a representative sample of natural origin fish (e.g., timing, size); mating the fish using factorial designs to minimize within family variation and maintain genetic diversity; and isolating the offspring of each spawned fish until its disease history has been determined. Those families with high pathogen loadings are culled to reduce the transfer of diseases and increase survival during artificial culture. During the rearing period, fish densities are kept low and three acclimation ponds are used to increase the in-river distribution of returning adults. When the fish are released, the juveniles are allowed to volitionally leave their raceways. Moreover, different fish cultural approaches are being systematically tested. They become part of the standard hatchery practices if they provide survival benefits.

Three innovative rearing approaches are being evaluated: semi-natural rearing, predator avoidance training, and male precocity reduction. Semi-natural rearing environments were compared to best conventional hatchery practices. The semi-natural rearing treatment consisted of raceways equipped with underwater feeders, sidewalls and substrate painted in a camouflaged fashion, suspended in-water structure, and overhead cover. Preliminary results indicate that this treatment did not increase post-release survival of smolts in a five-year study. Predator avoidance training using mergansers also did not improve post-release survival of smolts in two years of study. A high rate of precious maturation in hatchery males (average of 22% of total production) in their second year of life, prompted a treatment to attempt to reduce precocity. A small-scale experiment indicated that growth manipulation could reduce precocity. This experiment has been expanded to a full-facility experiment and we are now conducting a five-year study to test whether manipulating growth can be used to reduce precocity.

Preliminary results indicate that average hatchery fish recruitment (HOR) has been higher than wild fish recruitment (NOR)(Table 3). The disparity between Upper Yakima CESRF and wild/natural returns per spawner is actually greater than that depicted in Table 3 since all CESRF fish have their adipose fins clipped and are therefore subjected to higher harvest rates during those years selective fisheries occur downstream of the Yakima River mouth in the main stem Columbia River. The redd counts in the Teanaway Basin also increased substantially. For example, during 2002, the number of redds in the Teanaway Basin was 110, which is over 20 times the prior 10-year average (due almost entirely to fish returning from the Jack Creek Acclimation site). During 2004 the number of redds was 129.

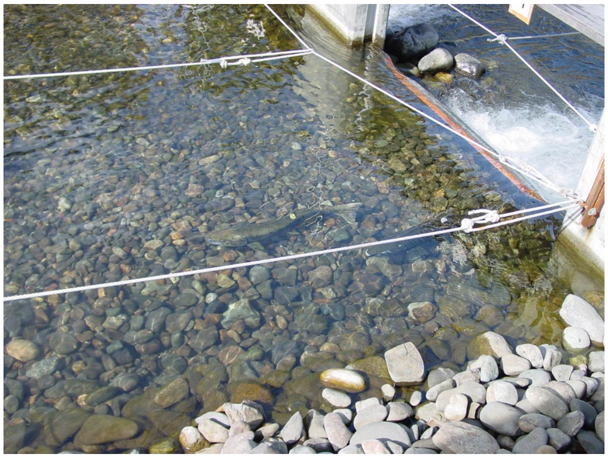
Table 3. Estimated number of spawners, adult returns, and returns per spawner (R:S) to the Yakima River Basin by population, brood years 1997-2001.

Brood	Upper Yakima Wild			Upper Yakima CESRF			Naches/American Wild		
Year	Spawners	Returns	R:S	Spawners	Returns	R:S	Spawners	Returns	R:S
1997	1,204	6,613	5.49	261	8,670	33.22	1,133	6,242	5.51
1998	390	3,383	8.68	408	9,765	23.93	917	4,882	5.32
1999	1,021	942	0.92	738	843	1.14	418	843	2.02
2000	11,864	8,649	0.73	567	4,599	8.11	4,112	2,457	0.60
2001	12,084			595			5,832		

Although this is encouraging, these fish must also reproduce successfully and produce fish that survive well in natural environments.

Due to the difficulty and expense of evaluating reproductive success of large populations of hatchery and wild fish in the natural environment, we constructed an observation stream (spawning channel) adjacent to the Cle Elum Hatchery. The stream is being used to compare the reproductive success of hatchery- and wild-origin spring chinook reproducing in a quasi-natural setting. Recent investigations on salmonid fishes have indicated that exposure to hatchery environments during juvenile life may cause significant behavioral, physiological, and morphological changes in adult fish. These changes appear to reduce the reproductive competence of hatchery fish. In general across all species, males are more affected than females; species with prolonged freshwater rearing periods are more strongly impacted than those with shorter rearing periods; and stocks that have been exposed to artificial culture for multiple generations are more impaired than those with a relatively short exposure history to hatchery conditions.

We found that differences in the reproductive competency of hatchery- and wild origin spring chinook that were placed in the spawning channel was influenced by competition strength. When intrasexual competition among females was relatively high, hatchery females were 3 to 10% less effective at producing offspring as wild origin females. Yet when intrasexual competition was reduced, hatchery females were comparable to wild females in their capacity to produce progeny. In the study populations that we have examined to date, hatchery males were on average 85% as effective as wild males in producing offspring. Additional replications of such evaluations are being carried out to determine if the differences seen will be replicated. The approach we are taking to compare the reproductive competency of hatchery and wild fish is to first determine the factors that are strongly linked to reproductive success, based on micro-satellite pedigree analyses of progeny, and then assess whether significant differences occur in the expression of these traits based on fish origin. Pedigree analyses on adults placed into the observation stream in 2004 are nearing completion and behavioral analyses of data collected since 2002 are currently underway.



If we find differences in the adult recruitment between hatchery and wild fish, then it is important to know what caused those differences. Differences could be due to fish culture (environmental effects), genetics, or a combination of both. A large-scale test of the domesticating effects of supplementation and continuous hatchery culture is being implemented to determine if any observed differences are genetic. The primary design consists of comparing three lines- a wild control line, a supplemented line, and a hatchery control line- for 13 adult and 17 juvenile traits. Traits vary in frequency of evaluation from annually to once per generation. By comparing the supplemented line to both controls, we will address two key questions: 1) how much domestication is incurred by a population undergoing YKFP-style supplementation; and 2) how much less domestication is incurred under YKFP-style supplementation than would be incurred under continuous hatchery culture? Summaries of the early stages of domestication research are presented in Table 4.

Table 4. Progress of domestication selection experiment by trait.

Trait	**Summary**
Adult	
Adult-Adult Survival	The hatchery recruitment rate has been higher than the wild recruitment rate every year (Table 3). The disparity between Upper Yakima CESRF and wild/natural returns per spawner is actually greater than that depicted in Table 3 since all CESRF fish have their adipose fins clipped and were therefore subjected to higher harvest rates during those years in selective fisheries downstream of the Yakima River mouth.
Age composition by sex	No significant differences were observed between supplementation and wild origin adult returns (X^2-*test*; p>0.05), but were in 2003 (X^2-*test*; p<0.01) primarily due to strong return of natural origin age-4's and strong return of supplementation origin age-5's.
Size-at-age by sex	Natural origin adults were larger than supplementation adults each year between 2000 and 2004. Natural age-3 returns were significantly larger than supplementation returns every year (mean difference = 2.7 cm and 0.3 kg; ANOVA; p<0.01) and were also significantly larger in 2001, 2002 and 2003 age-4 (mean difference 1.7 cm and 0.3 kg, ANOVA; p<0.01). Natural origin age-5 returns (mean difference 2.7 cm and 0.8 kg, ANOVA; p<0.01) were also significantly larger. There were no significant temporal trends in size over the period 2001 to 2004. No significant body size related sex-effects were detected for either age-3 or age-4 returns.
Sex ratio at age	There were no significant differences between supplementation and wild origin adult fish between 2001 and 2004 (X^2-*test*; $p \geq 0.213$).
Migration timing to trap	Some significant differences have been observed in the temporal distribution of supplementation and wild origin fish passing Roza Adult Monitoring Facility (Kruskal-Wallis ANOVA; p<0.05), but there is no consistent trend at this time. Consistent differences in median passage timing at RAMF by age have been observed (i.e., age-5 earliest<age-4<age-3 19 days later).
Spawning timing	There were no significant differences in 2001, 2002 and 2004 carcass recovery data (Kruskal-Wallis ANOVA; p>0.48). Supplementation fish matured 7 days earlier on average at CESRF each year (Kruskal-Wallis ANOVA; p<0.01). In 2001, the effective spawn timing of production broodstock was moved even earlier than naturally spawning fish because eggs from BKD infected females were removed from production and they represented almost exclusively the latter half of the run.
Fecundity	Fecundity of age-4 supplementation females was lower than wild origin females by 8%. No significant differences between body size/fecundity relationships of supplementation and wild origin (ANCOVA; p>0.15) were detected.

Table 4. (continued).

Trait	Summary
Adult (continued)	
Egg size	No consistent difference in mean egg weights of supplementation and wild origin females has been observed. Eggs of age-5 females are significantly larger than age-4's (ANOVA; $p<0.01$).
Reproductive effort	No difference between supplementation and wild origin females (2001-2004) or male (2003) reproductive effort has been observed (ANOVA; $p>0.05$).
Male and female fertility	Of the dead eggs we collected from the isolettes in 2004, 98% of the Hatchery mortalities were not fertilized and 97% of the wild mortalities. Thus, the vast majority of dead eggs were due to not being fertilized and on average only 2-3% died after being fertilized. Egg mortality to the eyed egg stage averaged 76% and 86% for hatchery and wild females, respectively.
Adult morphology at spawning	Significant differences between upper Yakima HOR, upper Yakima NOR, and Naches NOR morphology were found in 2003 returns (MANOVA; $p<0.01$); the first year analyzed to date. Morphological variation was examined in hatchery-and natural-origin 4-yr old Yakima spring Chinook of both sexes returning to the Upper Yakima in 2002-2004. Preliminary analyses indicated that in both sexes, statistically significant differences in shape exist between origin types and within years.
Adult spawning behavior	Positive and significant correlations between various agonistic and reproductive behaviors in males placed into an observation stream have been directly linked to their reproductive success. However, only two populations have been evaluated in this fashion and no statistical comparisons between these traits and the origin of the male fish examined have been performed. The potential affect of eight factors on the capacity of females to produce offspring in the observation stream was also performed on two populations. Two factors, longevity (hours alive in the observation stream) and redd guarding, proved to be the most important. Females that lived for relatively long periods of time and successfully guarded their redds from other females produced the most offspring.
Adult spawning success	The reproductive success (capacity to produce fry) of hatchery and wild fish has been examined in six populations placed into a controlled-flow observation stream. Mixtures of hatchery and wild spring Chinook were allowed to spawn naturally in the stream and microsatellite DNA samples were collected from their offspring. DNA samples from five of these populations have been subjected to pedigree evaluations making it possible to estimate the number of offspring produced by each adult. In four of the populations, females were allotted 10 to 12 m^2 of space (high density populations) while in two others they were provided 22 m^2 of space

Table 4. (continued).

Trait	**Summary**
Adult (continued)	
Adult spawning success (continued)	(low density populations). The pedigree assessments showed that hatchery females were 4 to 18% less successful at depositing their eggs and had poorer (3 to 10%) egg-to-fry survival rates than wild females in the four high-density sections. Conversely, in the one low-density section so far examined, hatchery-origin females were better at depositing their eggs (+12.5%) and achieved a higher egg to fry survival rate (+3.4%). Although preliminary, these results suggest that F1 hatchery origin females are probably as reproductively competent as wild cohorts when competition for space is relaxed. The pedigree analyses also disclosed that reproductive success in males was more variable than in females. In addition wild 4 and 5 yr-old males produced the most offspring. Hatchery 4 and 5 yr-old males were on average about 85% as effective at producing offspring. Jacks were 32% as effective and precocious males were approximately 17% as effective as the wild 4 and 5 yr-old males. Pedigree assessments are being performed on fry produced from the other low-density population. Moreover, another low-density population will be placed into the observation stream in 2005.
Juvenile	
Emergence timing	We believed that water temperatures did not vary between experimental vessels, since they were on a common water source. However, it was found that water temperatures did vary significantly between vessels and emergence timing cannot be compared until a method is found to account for inter-vessel variation in water temperature.
K_D at emergence	There was a significant positive relationship between K_D values and egg weight for both hatchery and wild fry ($R^2 > 0.42$, $p < 0.001$). The ANCOVA of K_D and Egg weight for 2002, 2003 and 2004 all showed that hatchery and wild origin relationships had equal slopes ($P > 0.26$), but significantly different means adjusted for egg weight ($p < 0.02$). The difference in K_D means is very small and is perhaps not biologically meaningful. However, hatchery origin samples (means ranged from 1.911 to 1.916) were consistently greater than wild samples (means ranged from 1.892 to 1.895).
Egg-fry survival	In comparisons of supplementation and wild origin single-pair *inter se* matings there have been no significant differences in egg-to-fry survival between groups (Kruskal-Wallis ANOVA; $p > 0.13$).

Table 4. (continued).

Trait	**Summary**
Juvenile (continued)	
Occurrence of developmental abnormalities	Occurrence of abnormalities in emergent fry were very low (<0.9%), in general. No significant supplementation and wild origin differences were observed between 2002 and 2004. In 2001, HOR values were significantly greater than NORs by 0.5% (ANOVA; p=0.04).
Fry-smolt survival in a hatchery environment	We have found that there was bias in the counts of eggs estimated by the automated egg counter. We are investigating the best way to estimate fry abundance. Data analysis is incomplete.
Juvenile morphology at release	Analysis of shape differences between progeny of hatchery- and natural-origin parents is in progress.
Smolt-to-smolt survival	Natural origin smolt-to-smolt survival was significantly greater than that for hatchery-origin fish for four of five brood years. Higher survival of natural origin fish was expected since they were exposed to and adapted to the river environment, including predation, above Roza for a much longer period than hatchery-origin fish. For the single brood year, 1999, when the natural origin and hatchery-origin smolt survival indices did not significantly or substantially differ, the flows for the associated outmigration year, 2001, were extremely low.
Natural smolt production	Rigorous comparisons have not been made yet, because we suspect bias in our current estimates at Prosser Dam. Primary sources of bias are associated with our estimates of entrainment rate and canal survival. These sources of bias are currently being evaluated and corrected.
Smolt-to-adult survival of hatchery-origin fish	There are estimates of smolt-to-adult survival for the first three broods. There are no significant differences between the OCT and SNT effects on the survival from juvenile-release-to-adult passage at Roza Dam on the Upper Yakima River. The 1997- and 1999-brood analyses are based on a pooling of all return-age cohorts (age 3 to age 5 returns); the 2000-brood analysis is based on only age 3 and 4 returns, 2004-return-year age-5 adults are still being evaluated.
Smolt out-migration timing	Mean travel times in migration year 2005 from the Clark Flat acclimation site to Prosser, McNary, John Day and Bonneville dams were calculated by day of release. Preliminary analyses of unweighted means suggest that there was no difference in travel time between the offspring of 1) hatchery and 2) wild parents released as smolts from the Clark Flat acclimation site. Data analysis on travel time from other release locations is in progress.

Table 4. (continued).

Trait	**Summary**
Juvenile (continued)	
Food conversion efficiency Juvenile length-weight relationships	Analysis in progress. It is likely that experimental power is inadequate to detect anything other than very large differences. If so, this trait should be dropped from the design. No difference between supplementation and wild origin fry length and body weight relationships have been observed (ANCOVA; $p>0.32$).
Agonistic-competitive behavior	Offspring of wild origin fish dominated 4% more contests than offspring of hatchery origin fish ($P\leq0.05$). Dominance was not significantly different in the scramble competition trials ($P>0.05$). Wild fish initiated more agonistic interactions than hatchery fish in both contest and scramble trials. There were no differences in the frequency of different types of agonistic interactions that were used by hatchery and wild fish. We also found that dominant fish grew more than subordinate fish in both contest and scramble trials ($P\leq0.05$).
Predator avoidance	Wild origin juveniles had 2% higher survival than similar-sized supplementation origin fish from 2002 and 2003 upper Yakima Basin parents ($P<0.05$).
Incidence of precocious maturation in production raceways	Mean precocity rates of male progeny from first generation hatchery parents were 14% (brood year 2002) and 11% (brood year 2003). Mean precocity rates of male progeny for natural origin parents were 40% (brood year 2002) and 21% (brood year 2003).

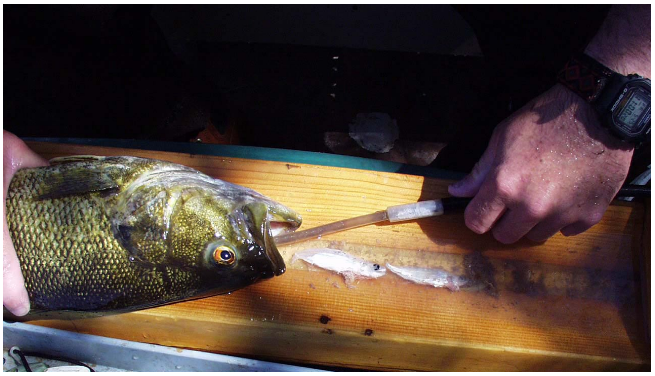
In order to evaluate supplementation effectively, it is important to discriminate between aspects under the control of YKFP personnel (e.g., fish culture) and those that are not. Changes in the environment and harvest management are factors that can have a dramatic affect on natural production. The YKFP has a goal of increasing the productivity and capacity of the Yakima Basin. This is accomplished through a variety of habitat related strategies. Strategies that are used to accomplish this goal include:

- Prioritization of most beneficial habitat actions
- Habitat and water right purchases in priority areas
- Re-establishment of connectivity to productive side channels, floodplains and tributaries
- Habitat restoration through in-stream and out-of-stream activities
- Assessing habitat protection and restoration actions
- Evaluation and mitigation of land use actions that pose a threat to watershed productivity

However, there are many environmental factors that are outside of the control of the YKFP. For example, the flow management of the Yakima Basin is largely controlled by the United States Bureau of Reclamation. Existing water and land use regulations do not effectively protect watershed functions, and continued population growth will make watershed management more challenging. Out-of-basin harvest is also outside of the scope of the project and yet can have a large impact on adult recruitment and project evaluation. This is especially true since project monitoring and evaluation requirements mandate the use of extensive marking protocols including adipose fin-clipping, while state and federal fishery managers are increasing efforts to target adipose fin-clipped fish.

While harvest management outside the Yakima Basin is outside of the control of the YKFP, in-basin harvest is influenced by the YKFP. For instance, currently there is selective harvest of hatchery-origin adipose-clipped fish by sport anglers in the Yakima River to manage the proportion of hatchery fish on the spawning grounds and minimize impacts to Naches Basin and upper Yakima natural-origin fish. The Yakama Nation uses maximum proportion management by tribal fishers to reduce impacts to natural populations. The co-managers have successfully managed all in-basin harvest (tribal and sport) to limit the combined exploitation rate to no more than 20 percent since hatchery adults began to return in 2000.

Current evaluations have identified that smallmouth bass, northern pikeminnow, and piscivorous birds are consuming large numbers of salmonids. For example, smallmouth bass in the lower Yakima River consumed an average of 188,058 salmonids each year from March 22 to June 16, 1998 to 2002, and of these, only 2,873 were yearling salmonids (primarily spring Chinook salmon). From 1999 to 2002, smallmouth bass predation on all yearling salmonids never exceeded 0.6% of the annual production of hatchery and wild fish combined. Estimated smallmouth bass consumption of hatchery ocean-type (fall-run) Chinook salmon has only comprised up to 4% of the annual production of these fish. The diet of northern pikeminnow is comprised of a high proportion of salmonids, including yearlings. Channel catfish have also been captured with salmonids in their gut. Unfortunately, calculating an abundance estimate for channel catfish and northern pikeminnow has been challenging. This has resulted in an inability to estimate the number of salmonids consumed by these two predators. Piscivorous birds, particularly gulls, common mergansers, and American white pelicans are great enough in abundance and bioenergetic capacity to consume large numbers of salmonids. Unfortunately, we have not secured adequate numbers of stomach contents to rigorously estimate the number of salmonids consumed by birds throughout the Yakima River basin.



Density dependent relationships between chinook salmon abundance and growth and survival exist in the upper Yakima Basin. Larger numbers of fall parr are correlated with smaller size. An asymptotic relationship exists between parent abundance and fall parr abundance. Competition indices suggest that competition for food is stronger than competition for space.

2. Can integrated hatchery programs limit genetic impacts to non-target chinook populations?

Genetic impacts to non-target chinook populations can occur if fish produced from a hatchery stray into areas where other populations or stocks spawn. If hatchery fish interbreed with individuals from these populations, then there is a risk that adaptations or genetic variability among populations will be lost. However, straying occurs in natural populations, and this natural rate can be used to assess whether hatchery populations show a greater or lesser tendency to return to their natal streams. Straying of hatchery fish can occur because of inappropriate imprinting or from natural tendencies to seek new spawning areas.

Two measures of straying can be measured. The first is the proportion of the returning hatchery adults that do not spawn in their natal areas and the second is the proportion of a non-target population that consists of strays. Measured either way, the YKFP has very low rates of straying and is within natural levels. An analysis of CESRF PIT detections at out-of-basin sites that were not later detected at Roza Dam indicates a potential stray rate to out-of-basin locations of less than 2% of all returning CESRF adults. Prior to 2004, no CESRF fish had been detected on the spawning grounds in the non-target Naches and American River systems. During 2004, four hatchery salmon carcasses were found in the Naches system, but it is unclear whether these were CESRF fish. Even within the upper Yakima Basin, there is site fidelity to specific acclimation sites. However, habitat quality also influences where fish spawn in the Yakima River. For example, few fish spawn near the Clark Flats acclimation site because of poor spawning habitat.

3. Can integrated hatchery programs limit ecological impacts to non-target populations?

Releases of large numbers of hatchery origin salmon have the potential to negatively impact other taxa that are not the target of enhancement (non-target taxa, NTT). Impacts may occur through a variety of ecological mechanisms such as competition, predation, and disease. We have used and planned a variety of techniques to manage ecological risks to NTT. These include risk assessment, risk containment, risk reduction, and implementation of an impact detection plan.

To determine changes in NTT status that could be related to hatchery smolt releases, we compared the abundance, size structure, and distribution of 14 non-target taxa before and six years after annual spring releases of about 1 million yearling smolts (coho and chinook) in the Yakima River, Washington. We compared any observed changes in status to predetermined containment objectives that were judged to reflect acceptable levels of impact. We utilized detection strategies that would balance our ability to detect changes and the chances of falsely associating a change with supplementation. With the exception of steelhead size, all of the changes we observed were within the containment objectives established for the project. The main stem Yakima River steelhead size index has decreased through the post-supplementation period although the decrease was not significant (-1%, $P>0.05$). Our analysis suggests that the depressed size of the steelhead index was not related to supplementation activities. For instance, we could not detect any differences in the sizes of rainbow trout between areas of high and low spring chinook abundance. Our results suggest that any impacts that might have been caused by releasing hatchery smolts into areas containing NTT were balanced or exceeded by the benefits (e.g., ecological release) of reducing the progeny of naturally produced fish or by the increase in nutrients provided by the hatchery and returning adults. The reduction of naturally produced fish in the river was the result of taking fish that would have spawned in the river into the hatchery. Results from status monitoring of 14 NTT after six years of hatchery releases suggest that risk containment actions are not necessary at this time.

4. Does supplementation increase harvest opportunities?

Higher rates of harvest can be maintained on populations that are more productive than populations that are less productive. If hatcheries are more productive (more adult recruits returning per adult taken into the hatchery) than natural environments (adults that spawn in the natural environment), then it can support a higher rate of harvest. Risks to less productive stocks (e.g., wild fish) can occur if they are harvested at rates that may be appropriate for more productive stocks. Spring chinook returns to the Yakima River mouth since 2000 have averaged nearly 14,500 salmon annually (compared to a pre-supplementation average of fewer than 3,500 fish annually), which has increased harvest opportunity both in and out of the Yakima River Basin. However, at this time it is difficult to assess how much of this improvement is due to natural factors such as improved freshwater and ocean conditions versus supplementation activities. Currently within the Yakima Basin, treaty reserved fisheries have harvested less than 12% of the returning adults on average annually since 1982 and non-tribal fishers are only allowed to keep hatchery fish.

Standard run reconstruction techniques are employed to derive reasonable estimates of harvest from the Columbia River mouth to the Yakima River mouth for spring chinook. Data from databases maintained by the United States versus Oregon Technical Advisory Committee (TAC) are used to obtain harvest rate estimates for the aggregate Yakima River spring chinook population and to estimate passage losses from Bonneville through McNary reservoirs. These data, combined with the Prosser Dam counts and estimated harvest below Prosser, are used to derive a Columbia River mouth run size estimate and Columbia River main stem harvest estimate for Yakima spring chinook. These data are being tracked and reported annually.

Based on available CWT information, harvest managers have long assumed that Columbia River spring chinook are not harvested in any abundance in marine fisheries as the timing of their ocean migration does not generally overlap either spatially or temporally with the occurrence of marine fisheries. The Regional Mark Information System (RMIS) will be queried regularly for any CWT recoveries of CESRF releases in ocean or Columbia River main stem fisheries. Based on the information reported to RMIS to date, it is believed that marine harvest accounts for about 0-2% of the total harvest of Yakima Basin spring chinook.

Since 2001, tribal and recreational fisheries combined have harvested an average of about 900 CESRF fish annually. During 2001, the first significant spring chinook salmon sport fishery in over 40 years occurred in the Yakima River and harvested an estimated 1,252 CESRF-produced spring salmon (adults and jacks) and 772 wild chinook. Sport and tribal fisheries combined harvested a total of 4,630 spring chinook (1,825 CESRF + 2,806 wild) or 19.9% of the total river mouth run size. During 2002, sport and tribal fisheries harvested an estimated 1,865 CESRF-produced spring chinook salmon, the highest number to date, with the sport harvest limited to adipose-clipped hatchery fish. Only 4,833 adult spring chinook salmon (wild and hatchery) returned in 2003 and no non-tribal sport fishery was opened. Total tribal harvest of CESRF fish was only 64 fish. Age 4 adults returning in 2003 experienced very poor survival as migrant smolts during the 2001 drought, which explains the poor performance of both wild and hatchery fish. In 2004, the sport fishery harvested 569 CESRF fish, but an estimated 109 wild fish that were released by mandatory rule are believed to have died from hooking injuries prior to spawning. Higher than expected post-release mortality occurred because the actual ratio of wild-to-hatchery fish was approximately 4:1 and anglers caught and released many wild fish to harvest a legal hatchery fish. The preseason forecast had predicted a more balanced wild-to-hatchery ratio of 1.4:1. In 2005, the sport fishery was not opened by WDFW because the preseason forecast indicated that a severe wild-to-hatchery imbalance would occur (4:1 or greater) and mainstem Columbia River in-season updates indicated that the total run size might be smaller than initially predicted. In fact, total Yakima River run size was 50% of the preseason forecast and the wild vs. hatchery ratio was 9:1.

All findings in this report should be considered preliminary until published in a peer-reviewed journal. A list of project reports and publications is attached. For further information and accomplishments please check the YKFP website at www.ykfp.org and the BPA website- http://www.bpa.gov/efw/pub/searchpublication.aspx under the Yakima Basin Reports or contact project personnel.

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