SPRING CHINOOK SALMON
SUPPLEMENTATION IN THE UPPER
YAKIMA BASIN: YAKIMA/KLICKITAT
FISHERIES PROJECT OVERVIEW

Annual Report 2007-2008
Prepared by:

Todd N. Pearsons¹, David E. Fast², William J. Bosch², Curt M. Knudsen³, Steve L. Schroder¹, Craig A. Busack¹, Mark V. Johnston², Scott R. Nicolai², David T. Lind², Anthony L. Fritts¹, Gabriel M. Temple¹, Christopher L. Johnson¹, Christopher R. Fredericksen², James J. Siegel², Melvin R. Sampson², and John A. Easterbrooks¹

¹ Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, Washington 98501-1091

² Yakama Nation
P.O. Box 151 Fort Road
Toppenish, Washington 98948

³ Oncorh Consulting

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97283-3621

Policy/Technical Involvement and Planning in the Yakima/Klickitat Fisheries Project; Project Number 1995-064-25; Contract 00038148
Yakima/Klickitat Fisheries Project’s Monitoring and Evaluation; Project Number 1995-063-25; Contract 00034450

September 2008
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 00034449 - WDFW

Yakima/Klickitat Fisheries Project’s Monitoring and Evaluation; Project Number 1995-063-25; Contract 00034450 – WDFW

Yakima/Klickitat Fisheries Project’s Monitoring and Evaluation; Project Number 1995-063-25; Contract 00035037 – Yakama Nation

Yakima/Klickitat Fisheries Project’s Management, Data, and Habitat; Project Number 1988-120-25; Contract 00035637 – 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. Preliminary results indicate that significant differences have been detected between hatchery and natural origin fish in about half of the traits measured in our monitoring plan and that these differences can be attributed to both environmental and genetic causes. For example, we have detected differences in hatchery and natural origin fish after only one generation of hatchery exposure for the following variables measured on adults: age composition, size-at-age, sex ratio, spawn timing, fecundity, egg weight, adult morphology at spawning, and spawning success. Significant differences in juvenile traits have also been detected: food conversion efficiency, length-weight relationships, agonistic competitive behavior, predator avoidance, and incidence of precocious maturation. Most of the differences have been 10% or less.

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. 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, however post-release survival of treated fish appears to be significantly lower than conventionally reared fish. 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 generally within containment objectives, or impacts that were outside of containment objectives were not caused by supplementation activities. However, 2007 marked the second year we detected statistically significant impacts to rainbow trout abundance and biomass in the Teanaway Basin that occurred between 1999 and 2007. The impacts to rainbow trout were likely the result of cumulative impacts from hatchery released Chinook salmon smolts, residualized spring Chinook salmon, and an increase in naturally produced parr. Fish and bird piscivores 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 could be countered by YKFP habitat actions that have resulted in: the protection of almost 1,000 acres of prime floodplain habitat, addition of wood into tributaries, 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. Additional habitat improvements implemented by other entities, including the Conservation Districts, counties and private interests are also continuing in the basin. Harvest opportunities for tribal and non-tribal fishers have also
been enhanced, but are variable among years. However, quantitative harvest objectives for the upper Yakima stock and all Yakima basin stocks combined have not been met in either the Columbia or Yakima rivers. 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 developed 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 quantitative objectives reported in Pearsons et al. (2006).

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Goal</th>
<th>Performance</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Natural Production of Target Species| Increase while maintaining the long-term fitness of the target population (see quantitative objectives; Pearsons et al. 2006) | Quantitative objectives for adults have been achieved but not for smolts. Differences in traits of hatchery and natural origin fish are a 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. Quantitative management objectives for natural production of upper Yakima and basin total spring Chinook adults have been achieved but objectives for naturally produced smolts have not been achieved.  
- Significant changes in many demographic and reproductive success traits indicate cause for concern. Recent data suggest significant genetic contribution to many of these changes.  
- Predation and competition may be limiting natural production objectives and may constrain the benefits of supplementation. |
| Harvest                             | Increase (see quantitative objectives; Pearsons et al. 2006)         | Increased, but objectives haven’t been met | - Tribal subsistence fisheries occurred on both hatchery and naturally produced fish in all years. Sport fisheries on hatchery fish have also occurred in the Yakima River in 3 of the |
7 years since 2001.
- Quantitative harvest objectives for the upper Yakima stock and all Yakima basin stocks combined have not been met in either the Columbia or Yakima rivers

<table>
<thead>
<tr>
<th>Genetics</th>
<th>Minimize genetic impacts to non-target taxa</th>
<th>Achieved to date</th>
<th>Stray rates are very low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology</td>
<td>Keep impacts to non-target taxa within containment objectives (see Pearsons et al. 2006)</td>
<td>Achieved for most taxa to date, but exceeded for steelhead in the Teanaway Basin between 1999 and 2007</td>
<td>Impacts for most species are within containment objectives or are currently not attributable to supplementation. Impacts to steelhead in the Teanaway Basin have exceeded containment objectives between 1999 and 2007, likely from Chinook supplementation.</td>
</tr>
</tbody>
</table>
| Habitat        | Protect the most productive stream reaches and increase productivity/capacity of freshwater environment so that quantitative objectives can be achieved. | Progress | Habitat protection, restoration, and tributary passage efforts 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. |
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 demographic, ecological, and genetic benefits and costs of supplementation. Quantitative objectives of the spring Chinook salmon component of the YKFP are presented in Pearsons et al. (2006).

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 heavily monitored 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. Furthermore, the relatively large size of the spring Chinook population allows for operational protocols that are considered to be among the best that are achievable. As such, results from the YKFP might be considered to be among the best that could be achieved in a supplementation program.

Table 2. Important milestones of the YKFP.

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

With a project of this magnitude, many management decisions 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. In addition, a formal Science and Management Conference is held annually to disseminate technical information, evaluate and integrate new information into the YKFP, and coordinate future work (Appendix 1). Management decisions are made within the frameworks of adaptive management and risk management.
This report updates findings through July 31, 2008 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 greater 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. 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., run 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 culture approaches are being systematically tested. They become part of the standard hatchery practices if they provide survival benefits.

Three innovative rearing approaches are being/have been 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 precocious 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 evaluating a three-year (BY 2002-2004) study to test whether manipulating growth can be used to reduce precocity without significantly impacting post-release survival. Preliminary results indicate that growth manipulation decreased precocious maturation but resulted in smaller fish that survived at lower rates than control fish. This treatment was suspended beginning with BY 2005 based on these preliminary results but analyses will continue as adults will still be returning through 2009 (5 year old progeny of BY 2004).
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 beginning in 2001 when selective fisheries first occurred downstream of the Yakima River mouth in the main stem Columbia River, because all CESRF fish have their adipose fins clipped and are therefore subjected to higher harvest rates. The harvest rates have been accounted for in Table 4. The redd counts in the Teanaway Basin also increased substantially from a pre-supplementation average of 3 redds per year to a post-supplementation average of 59 redds per year (due almost entirely to fish returning from the Jack Creek Acclimation site). During 2007, the number of redds in the Teanaway was 10.

Supplementation and habitat activities in the upper Yakima Basin appear to have significantly increased the number of redds relative to a control stream. The mean difference in upper Yakima (supplemented) and Naches (control) stock redd counts between 1981 and 2000 (before supplementation benefits) was 538 redds. During supplementation (2001-2007), the upper Yakima River redd counts averaged 1,584 higher than the Naches redd counts. The differences between these periods were significant (BACIP; P<0.004). Although higher productivity and distribution is encouraging, these fish must also reproduce successfully and produce fish that survive well in natural environments.

Table 3. Estimated number of spawners, adult returns, and returns per spawner (R:S) to the Yakima River Basin by population, brood years 1997-2003.

<table>
<thead>
<tr>
<th>Brood Year</th>
<th>Upper Yakima Natural</th>
<th>Upper Yakima CESRF</th>
<th>Naches Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spawners</td>
<td>Returns</td>
<td>R:S</td>
</tr>
<tr>
<td>1997</td>
<td>1,204</td>
<td>6,613</td>
<td>5.49</td>
</tr>
<tr>
<td>1998</td>
<td>390</td>
<td>3,383</td>
<td>8.68</td>
</tr>
<tr>
<td>1999</td>
<td>1,021</td>
<td>942</td>
<td>0.92</td>
</tr>
<tr>
<td>2000</td>
<td>11,864</td>
<td>8,776</td>
<td>0.74</td>
</tr>
<tr>
<td>2001</td>
<td>12,084</td>
<td>6,114</td>
<td>0.51</td>
</tr>
<tr>
<td>2002</td>
<td>8,073</td>
<td>2,342</td>
<td>0.29</td>
</tr>
<tr>
<td>2003\textsuperscript{a}</td>
<td>3,341</td>
<td>1,223</td>
<td>0.37</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Does not include age-5 adults returning in 2008.
Table 4. Estimated number of spawners, adult returns to the Columbia River mouth and returns per spawner (R:S) to the Columbia River mouth by population, brood years 1997-2003.

<table>
<thead>
<tr>
<th>Brood Year</th>
<th>Upper Yakima Natural</th>
<th>Upper Yakima CESRF</th>
<th>Naches Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spawners</td>
<td>Returns</td>
<td>R:S</td>
</tr>
<tr>
<td>1997</td>
<td>1,204</td>
<td>19774</td>
<td>16.42</td>
</tr>
<tr>
<td>1998</td>
<td>390</td>
<td>10556</td>
<td>27.07</td>
</tr>
<tr>
<td>1999</td>
<td>1,021</td>
<td>1411</td>
<td>1.38</td>
</tr>
<tr>
<td>2000</td>
<td>11,864</td>
<td>12637</td>
<td>1.07</td>
</tr>
<tr>
<td>2001</td>
<td>12,084</td>
<td>8599</td>
<td>0.71</td>
</tr>
<tr>
<td>2002</td>
<td>8,073</td>
<td>6363*</td>
<td>0.79</td>
</tr>
<tr>
<td>2003</td>
<td>3,341</td>
<td>441</td>
<td>1,400</td>
</tr>
</tbody>
</table>

*Preliminary; Does not include 5 or 6 year old fish. Assumes Columbia River harvest rates are equal for all stocks.

Quantitative management objectives for natural production of upper Yakima and basin total spring Chinook adults have been achieved (Table 5 and 6). Management objectives for smolts are not currently being met (Table 5 and 6).

Table 5. Natural production objectives for Upper Yakima Basin spring Chinook salmon. Values were estimated using the EDT and AHA models and are expressed as average annual abundances for different time strata under different harvest scenarios. Properly functioning conditions produce approximately 80% of historic conditions.

<table>
<thead>
<tr>
<th>Goal/Observed and performance period</th>
<th>Habitat Condition</th>
<th>Natural Origin Upper Yakima Smolts at Chandler</th>
<th>Natural Origin Adults at Roza</th>
</tr>
</thead>
</table>

*a preliminary estimate based on extrapolations of genetic data, may be underestimated during periods of high flow
b includes jacks
Table 6. Natural production objectives for *Entire Yakima Basin spring Chinook salmon*. Values were estimated using the EDT and AHA models and are expressed as average annual abundances for different time strata under different harvest scenarios. Properly functioning conditions produce approximately 80% of historic conditions.

<table>
<thead>
<tr>
<th>Goal/Observed and performance period</th>
<th>Habitat Condition</th>
<th>Natural Origin Smolts at Chandler</th>
<th>Natural Origin Escapement</th>
</tr>
</thead>
</table>

*a* may be underestimated during periods of high flow  
*b* includes jacks

The breeding success, or ability to produce juvenile offspring, of first generation hatchery fish produced from the CESRF was evaluated by creating mixed populations, or test groups, consisting of mixtures of wild and hatchery fish and allowing them to spawn in an artificial stream (BY 2001 through 2006). No differences were detected in the egg deposition rates of wild and hatchery females. Pedigree assignments based on microsatellite DNA, however, showed that the eggs deposited by wild females survived to the fry stage at a 6% higher rate than those spawned by hatchery females. Subtle differences between hatchery and wild females in redd abandonment, egg burial, and redd location choice may have been responsible for the difference observed. Body size did not affect the ability of females to spawn or the survival of their deposited eggs. How long a female lived was positively related to her breeding success but female origin did not affect longevity. The density of females spawning in portions of the stream affected both egg deposition and egg-to-fry survival. Females spawning in parts of the artificial stream with relatively high instantaneous densities (< 5 m²/female) retained more eggs and produced fewer offspring than those spawning at lower densities (> 19 m²/female). No difference, however, was found in the overall distribution patterns of the two types of females in the artificial stream.

Behavioral differences between hatchery- and wild males were observed. Wild males had higher mean attack rates (*P* = 0.01), exhibited greater positive agonism (*P* = 0.01) and higher social dominance (*P* = 0.02) than hatchery males. No difference was seen, however, in the frequency of courting behaviors between the two types of males (*P* = 0.16). All of these behavioral traits were positively correlated with one another and with male breeding success. Additionally, male breeding success increased with body weight; however this trait appeared to be less important than either agonism or courting behavior on the ability of males to produce newly emerged fry. Despite the behavioral differences observed, DNA-based pedigree analyses showed that hatchery and wild males mated with similar numbers of females (*P* = 0.39) and had comparable breeding success (*P* = 0.22). Consequently, a single generation of hatchery exposure appeared to have a low impact on male breeding success. If the behavioral differences observed are
genetically controlled, however, then continued exposure to hatchery conditions would likely reduce breeding success in hatchery males when they spawn under natural conditions.

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 14 adult and 15 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?

Preliminary results indicate that significant differences have been detected in about half of the traits measured and that differences can be attributed to both environmental and genetic causes. For example, we have detected differences in hatchery and natural fish after only one generation of hatchery exposure for the following variables measured on adults: age composition, size-at-age, sex ratio, spawning timing, fecundity, egg weight, adult morphology at spawning, and spawning success. Preliminary data from 2007 recoveries indicate that there is a significant genetic component to some of these differences. Significant differences in juvenile traits have also been detected: food conversion efficiency, length-weight relationships, agonistic competitive behavior, predator avoidance, and incidence of precocious maturation. Most of the differences have been 10% or less. Summaries of the early stages of domestication research are presented in Appendix 2.
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
- 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 and climate change 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 example, for Yakima River mouth run sizes that are less than 12,000 total adults (hatchery + natural-origin) and the proportion of the run that is natural-origin is less than 60%, 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. In river estimates have put the population of northern pikeminnow at 142-516 fish per mile. The abundance and consumption rate of northern pikeminnow suggests that predation on smolts may be significant with an expanded consumption estimate of 4,217 salmonid smolts consumed per day between the confluence with the Naches and Prosser Dam during the spring of 2007. 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 catfish.

Common mergansers, American white pelicans, double-crested cormorants and gulls are great enough in abundance and bioenergetic capacity to consume large numbers of salmonids. Mergansers were the most significant predator in the upper river, potentially consuming 91-98% of the fish biomass consumed by all bird predators in that stratum. However an earlier dietary analysis of Yakima River mergansers found they eat a broad range of small fish with salmonids only becoming common in their diet during fall/winter. Mergansers have not shown a numeric response to increases in the number of spring Chinook smolts in the Yakima River over the last 10 years.

Pelicans, which inhabit the lower and middle Yakima River, could potentially consume the entire hatchery production of salmon smolts of all species in the lower river, yet only supply 26% of their dietary requirements. Pelican numbers at the Chandler fish bypass have declined to 9.9 birds per day from 57 birds in 2005, with cormorant numbers increasing. Based on bioenergetic and behavioral models, Chandler pelicans and Horn Rapids gulls could potentially consume up to 10% of the total Yakima Basin hatchery production of salmon smolts of all species. However, pelicans feeding at Chandler Fish Bypass often capture fish that are substantially larger than spring Chinook smolts, including adult chiselmouth, sucker, and pikeminnow. Correlation analysis suggest that pelicans and gulls at Chandler Fish Bypass and Horn Rapids Dam are not responding to passage of spring Chinook smolts, but may be tracking the passage of coho smolts, although this did not hold true for pelicans in 2007 as discharge appeared to drive pelican numbers.

The higher the river volume during peak smolt out-migration, the lower the predation rate by birds. Fish exiting Chandler Bypass are vulnerable to bird predation at low river flows, while being largely secure from bird predation at high flows. With the
exception of gulls at Horn Rapids in 2007, the number of salmon smolts consumed by birds at Horn Rapids Dam and Chandler has declined each year since 2002. Examining a greater number of stomach contents of American white pelicans and double-crested cormorants from the Yakima River would help us estimate the number of salmonids consumed by birds in the Yakima Basin. Pelicans will be tagged in 2008 to track movement and feeding patterns and PIT tags found at nesting and roosting sites will be used to generate species-specific consumption estimates.

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 a fall parr abundance index. Competition indices suggest that competition for food is stronger than competition for space. However, the amount of space and food available to juvenile salmon may be strongly influenced by artificially high summer flows. Unless the capacity of the environment increases (e.g., altered stream flows, increased passage), the natural production benefits of supplementation will be largely confined to years when natural origin fish escapement is below the carrying capacity of the environment.

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. Straying is a natural phenomenon, keeping levels of diversity high in population groups. The risk occurs from hatchery fish when hatchery fish stray at unnatural levels or to unnatural destinations. Straying of hatchery fish can occur because of inappropriate imprinting or from natural tendencies to seek new spawning areas.

Two measures of straying are commonly measured. The first is the proportion of the returning hatchery adults that do not spawn in their natal areas, which measures straying propensity and the second is the proportion of a non-target population that consists of strays. It is the second that is generally more important for assessment of genetic risk: a small stray rate from a very large population can genetically swamp a
small population. Measured either way, however, the YKFP spring chinook program has
very low rates of straying and is within natural levels. Since program inception, a total of
8 adipose-clipped carcasses (assumed hatchery-origin) have been detected on the
spawning grounds in the non-target Naches and American River systems during annual
spawner surveys. This includes 1 fish in 2002, 4 in 2004, 2 in 2005, 1 in 2006, and none
in 2007. It is unclear whether these were CESRF fish, but assuming they were, they
comprised less than 0.25% of the estimated annual spawning escapement into the Naches
system. 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.

An analysis of CESRF PIT detections at out-of-basin sites that were not later
detected at Roza Dam indicates a potential average annual stray rate to out-of-basin
locations of less than 2% of all returning CESRF adults. Because almost all this
information is based on PIT tag detections at dams, the impact in terms of recipient
population is not known. Because of other research objectives, the project only began
using the common snout location for placement of coded wire tags (CWT) in most fish
beginning with brood year 2004. Therefore, a more complete examination of out-of-
basin CWT recoveries is pending until sufficient recoveries from these fish begin
occurring in 2008 and subsequent years.

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.

We evaluated the impacts of spring Chinook salmon supplementation and coho
salmon reintroduction (hereafter supplementation) to non-target fish taxa after nine years
of stocking approximately one million yearling smolts annually in the upper Yakima
Basin between 1999 and 2007. Field methods included backpack electrofishing and
snorkeling in tributaries, and drift-boat electrofishing in the main stem. We used three
sequential steps in our evaluation: First, we determined if spatial overlap occurred
between supplementation fish and non-target taxa. Second, if overlap occurred, we
determined if a change in abundance, size, or biomass occurred during supplementation.
Lastly, if a change occurred we determined if the change could be reasonably attributed
to supplementation. Spatial overlap and changes in abundance, size, or biomass were
determined to be significant if they exceeded containment objectives. Salmon rarely
overlapped cutthroat and bull trout in tributaries, but some overlap of cutthroat occurred
in relatively high elevations of the main stem, and considerable overlap with rainbow
tROUT occurred in tributaries and the main stem. Salmon overlapped mountain whitefish
and sucker species in the main stem, and dace and sculpin species in tributaries. With the
exception of steelhead, the lower 90% confidence limit of abundance, size, and biomass was above the containment objective for non-target taxa that overlapped significantly with salmon. We used rainbow trout as an analog for steelhead. The lower 90% confidence limit of rainbow trout size in tributaries and in the main stem, were below our containment objectives. Comparisons of rainbow trout size in tributaries, and size in main stem sections with relatively high and low salmon abundance revealed that these changes were unlikely to be the result of supplementation (BACIP P>0.05). Our data indicate that early stages of salmon supplementation have not impacted valued species in the upper Yakima Basin beyond predetermined containment objectives, but the weight-of-evidence suggests that salmon supplementation is limiting increases of abundance and biomass of rainbow trout downstream of the Jack Creek acclimation/release site relative to control streams in the Teanaway Basin.

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 (adults and jacks) to the Yakima River mouth since 2000 have averaged 12,400 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 allowed to keep hatchery fish when the total river mouth run size is less than 12,000 adults and the percentage of hatchery-origin adults is greater than 40 percent.

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 spring Chinook population destined for tributaries above Bonneville Dam 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 (assuming Yakima spring Chinook are harvested in
Columbia River fisheries at the same rate as all stocks destined for tributaries above
Bonneville Dam). 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) is 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 660 CESRF and 940 wild/natural spring Chinook annually. Also since 2001, in-
basin harvest rates have averaged 11.7% on wild and 10.3% on CESRF fish, with tribal
harvest rates averaging 8.9% and recreational harvest rates averaging 2.4% of the total
Yakima Basin return of spring Chinook. Successful recreational fisheries for spring
Chinook in the Yakima River are dependent on several conditions: a large number
(preferably greater than 10,000) of returning spring Chinook, a return of wild/natural fish
that does not far outnumber the return of hatchery fish, and favorable water conditions.
This combination of conditions occurred in 2001, 2002, 2004, and 2008; recreational
fisheries were precluded in other years.

Quantitative harvest objectives for the upper Yakima stock and all Yakima basin
stocks combined have not been met in either the Columbia or Yakima rivers (Table 7 and
8).

Table 7. Harvest objectives for **Upper Yakima Basin spring Chinook salmon**. Values
were estimated using the EDT and AHA models and are expressed as average annual
abundances for different time strata under different harvest scenarios. Properly
functioning conditions produce approximately 80% of historic conditions.

<table>
<thead>
<tr>
<th>Goal/Observed and performance period</th>
<th>Habitat Condition</th>
<th>Columbia River and Ocean Harvest (hatchery and natural origin fish)</th>
<th>Yakima Basin Harvest (hatchery and natural origin fish)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 year goal (2005-2015)</td>
<td>Current Yakima Basin at capacity and 2.99% smolt-to-adult survival</td>
<td>1,777-2,590</td>
<td>1,031-1,854</td>
</tr>
<tr>
<td>Observed (2005-2006)</td>
<td>Current</td>
<td>900&lt;sup&gt;a&lt;/sup&gt; (87.7)</td>
<td>387 (41)</td>
</tr>
</tbody>
</table>

<sup>a</sup> assumes no marine harvest, numbers in parentheses are 1 standard deviations
Table 8. Harvest objectives for *Entire Yakima Basin spring Chinook salmon*. Values were estimated using the EDT and AHA models and are expressed as average annual abundances for different time strata under different harvest scenarios. Properly functioning conditions produce approximately 80% of historic conditions.

<table>
<thead>
<tr>
<th>Goal/Observed and performance period</th>
<th>Habitat Condition</th>
<th>Columbia River and Ocean Harvest (hatchery and natural origin fish)</th>
<th>Yakima Basin Harvest (hatchery and natural origin fish)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 year goal (2005-2015)</td>
<td>Current Yakima Basin at capacity and 2.99% smolt-to-adult survival</td>
<td>1,996-2,879</td>
<td>1,184-2,117</td>
</tr>
<tr>
<td>Observed (2005-2007)</td>
<td>Current</td>
<td>1,271&lt;sup&gt;a&lt;/sup&gt; (18.6)</td>
<td>451 (162)</td>
</tr>
</tbody>
</table>

<sup>a</sup> assumes no marine harvest, numbers in parentheses are 1 standard deviations

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](http://www.ykfp.org) and the BPA website- [http://www.bpa.gov/efw/pub/searchpublication](http://www.bpa.gov/efw/pub/searchpublication) or contact project personnel.
Project Reports Produced during FY07 (Arranged alphabetically)


Peer-reviewed Publications Produced in Association with the YKFP (in chronological order)


21


Pearsons, T. N. 2002. Chronology of ecological interactions associated with the life-


of Fishes.


Pearsons, T. N. In Review. Operating hatcheries within an ecosystem context using the adaptive stocking concept. Fisheries.


Acknowledgments

We would like to thank the many people and agencies that have provided policy, scientific, administrative, legal, and financial support for this project. Unfortunately, we are unable to list all of the contributions that have been made by the hundreds of people who have supported this project. However, there are a few people who have had a long-
term and lasting impact on this project, such as Bruce Watson, Steve Leider, Bill Hopley, and Joel Hubble. Two consultants, Doug Neeley and Brenda James, have also contributed substantially to technical aspects of the project. Don Larsen provided the data about precocious maturation of males in hatchery raceways. Molly Kelly did much work to free up scientists to do technical work and produced the table in Appendix 1. We are thankful to Bonneville Power Administration for funding this work and to David Byrnes and Patty Smith who have participated in the project and administered the contracts.
## Table 1. Numbers and percentages of Yakima Basin Science and Management Conference participants by affiliation and year.

<table>
<thead>
<tr>
<th>Affiliation</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington Department of Fish and Wildlife</td>
<td>28</td>
<td>21</td>
<td>21</td>
<td>36</td>
<td>32</td>
</tr>
<tr>
<td>Yakama Nation</td>
<td>37</td>
<td>28</td>
<td>23</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td>United States Bureau of Reclamation</td>
<td>16</td>
<td>17</td>
<td>11</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Central Washington University</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Bonneville Power Administration</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>National Oceanic and Atmospheric Administration</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>United States Fish and Wildlife Service</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Other(^a)</td>
<td>40</td>
<td>39</td>
<td>43</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>148</strong></td>
<td><strong>125</strong></td>
<td><strong>113</strong></td>
<td><strong>174</strong></td>
<td><strong>162</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Affiliation</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington Department of Fish and Wildlife</td>
<td>19%</td>
<td>17%</td>
<td>19%</td>
<td>21%</td>
<td>20%</td>
</tr>
<tr>
<td>Yakama Nation</td>
<td>25%</td>
<td>22%</td>
<td>20%</td>
<td>22%</td>
<td>21%</td>
</tr>
<tr>
<td>United States Bureau of Reclamation</td>
<td>11%</td>
<td>14%</td>
<td>10%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Central Washington University</td>
<td>5%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>7%</td>
</tr>
<tr>
<td>Bonneville Power Administration</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>National Oceanic and Atmospheric Administration</td>
<td>6%</td>
<td>7%</td>
<td>5%</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>United States Fish and Wildlife Service</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Other(^a)</td>
<td>27%</td>
<td>31%</td>
<td>38%</td>
<td>36%</td>
<td>36%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>


## Table 2. Percent of attendance that was composed of speakers.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent of Total that were Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>29%</td>
</tr>
<tr>
<td>2005</td>
<td>40%</td>
</tr>
<tr>
<td>2006</td>
<td>49%</td>
</tr>
<tr>
<td>2007</td>
<td>33%</td>
</tr>
<tr>
<td>2008</td>
<td>32%</td>
</tr>
</tbody>
</table>
Appendix 2  
Progress of natural production and domestication monitoring plan by trait.

Number in parentheses of first column refers to trait description in Blankenship et al. 2007 (please consult this document for added information about the trait). % difference is expressed as 1) subtraction between the mean % values (termed “subtraction”); and 2) % higher or lower (difference/SN<sub>p</sub> or SH line value) (termed “division”). The % difference by division is reported in parentheses immediately after % difference by subtraction. Abbreviations are as follows: SN - naturally produced fish from the supplemented line.  
SN<sub>p</sub> – hatchery-origin progeny of naturally produced fish from the supplemented line.  
SH – hatchery-origin fish from the supplemented line.  
SHP – hatchery-origin progeny of SH adults.  
HC - fish from the hatchery control line.  
WC - natural-origin fish from the wild control line.  
WCP – hatchery-origin progeny of WC adults.  
All comparisons are significantly different (P<0.05) unless a P-value >0.05 is presented.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Numeric Difference</th>
<th>% Difference</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female recruits produced per naturally spawning female (A1)</td>
<td>Data have been collected for 2005 and 2006, but a statistical test will not be performed until 5 year old returns are available in 2007</td>
<td>Data have been collected for 2005 through 2007, but statistical analyses have not been completed, yet.</td>
<td>Unpublished</td>
</tr>
<tr>
<td>Target population natural spawning</td>
<td>Samples are being collected at Roza Dam. Analysis won’t be initiated until satisfactory number of samples and budget become available.</td>
<td>Samples are being collected at Roza Dam. Analysis won’t be initiated until satisfactory number of samples and budget become available.</td>
<td>Unpublished</td>
</tr>
<tr>
<td>Replacement rate (A2)</td>
<td>Age composition by sex (A3)</td>
<td>Size-at-age by sex (A4)</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------------</td>
<td>-------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td><strong>F₁:</strong> Most SH and SN fish of both sexes reached maturity at age 4 (&gt;76%), followed in magnitude by ages 3 and 5. However, SH mean age at maturation declined significantly due primarily to an increase in age 3 males over time, while SN mean age at maturation demonstrated no significant trend over time.</td>
<td><strong>F₁:</strong> For broodyears 1997 to 2000 mean lengths of 3–5-year-old SH fish were shorter than those of SN fish of the same age (differences of 2.7 cm for age 3, 1.7 cm for age 4, and 1.9 cm for age 5). Likewise, body weights of SH fish were lower than those of SN fish (differences of 0.3 kg for age 3, 0.3 kg for age 4, and 0.6 kg for age 5), representing a change in body size of between 0.5 and 1.0 standard deviation (SD).</td>
<td>Knudsen et al. 2006</td>
</tr>
<tr>
<td></td>
<td><strong>F₂:</strong> These general trends continued into BY2001, but then the SH age 3 proportion dropped dramatically in BY2002 and BY2003 to 12.4%.</td>
<td><strong>F₂:</strong> These general trends (SN&gt;SH) have continued into return years 2005 through 2007. In 2005 and 2007 age 3 mean SH length and weight distributions at RAMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>F₁:</strong> The SH male proportion increased by 270% from 8.5% to 22.9%, while the other SH and SN age/sex proportions remained relatively stable.</td>
<td><strong>F₁:</strong> POHP length SN larger than SH - Age 3 (6.7%), age 4 (2.4%), and age 5 (2.8%). Body weight SN larger than SH – Age 3 (19.0%), age 4 (5.8%), age 5 (8.7%).</td>
<td>Knudsen. 2007 and Knudsen 2008.</td>
</tr>
<tr>
<td></td>
<td><strong>F₁:</strong> The proportion of age 3 males dropped 84.7%, from BY2001 to BY2003 and returned to pre-supplementation levels.</td>
<td><strong>F₂:</strong> POHP length SN larger than SH - Age 3 (6.7%), age 4 (2.4%), and age 5 (2.8%). Body weight SN larger than SH – Age 3</td>
<td>Unpublished data: Knudsen. 2007, Knudsen 2008.</td>
</tr>
<tr>
<td><strong>Sex ratio at age (A5)</strong></td>
<td><strong>F₁</strong>: The proportion of SH males, primarily age 3, significantly increased from 38% to 49% over time for BY 1997-2000. Conversely, the sex composition of wild fish did not exhibit a similar increasing trend. The sex composition in BY1997-2000 SN and SH fish differed in three of four brood years. Although SH males began low relative to SN fish, but ended highest.</td>
<td><strong>F₁</strong>: Not applicable</td>
<td><strong>Knudsen et al. 2006</strong></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td><strong>F₂</strong>: These general trends have continued into return years 2005 to 2007, although the data have not yet been analyzed on a brood year basis. Analyses will be integrated with 2008 to assess the impacts in F₂.</td>
<td></td>
<td>Unpublished data: Knudsen. 2007, Knudsen 2008.</td>
</tr>
<tr>
<td><strong>Migration timing to trap (A6)</strong></td>
<td><strong>F₁</strong>: Median arrival timing of adult (&gt;age 4) SH and SN fish at RAMF showed no consistent difference between RY 2001 and 2004.</td>
<td><strong>F₁</strong>: No consistent difference.</td>
<td><strong>Knudsen et al. 2006</strong></td>
</tr>
<tr>
<td></td>
<td><strong>F₂</strong>: Adult SH and SN median passage date at RAMF differed significantly (SN earlier) by 7 and 6 days for RY 2005 and 2006,</td>
<td><strong>F₂</strong>: SH adult median passage was between 4.8 to 5.3% later than SN passage in RY2005 and 2006, respectively. SH jack</td>
<td>Unpublished data: Knudsen. 2007, Knudsen 2008.</td>
</tr>
</tbody>
</table>
respectively. SH jack median passage was 2 and 12 days later than SN jacks in RY 2005 and 2006, respectively. These were all significantly later each year in Kruskal-Wallis tests. median passage was between 1.2 to 12.2% later than SN passage in RY 2005 and 2006, respectively.

| Spawning timing (A7) | F1: Maturation timing of SH fish averaged 5.2 days earlier than SN fish at CESRF (RY2001-2004). | F1: Maturation timing of SH fish averaged 14.9% earlier than SN fish at CESRF (RY2001-2004) assuming an average 5 week (35 day) period of spawning. | Knudsen et al. 2006

F1: Initiation of in-river female spawning activity did not differ between SH and SN fish (RY2002-2005)

F2: This trend has continued into return years 2005 through 2007. In 2007 HC fish spawned earliest, followed by SH (1 day later), then by SN fish (5 days later).

F1: Initiation of in-river female spawning activity did not differ between SH and SN fish (RY2002-2005)

F2: Mean maturation timing of HC fish was 3.1% earlier than SH fish and 13.4% earlier in 2007.

Knudsen et al. submitted

Unpublished data: Knudsen. 2007.


F2: After adjusting for POHP, mean fecundity of HC (3,319.7 eggs; n=38) and SN (3,328.8 eggs; n=208) origin age 4 females were not significantly different (p=0.923). Mean fecundity in BY2002 was the lowest we have observed, reflecting the fact that age 4 body size was also the smallest recorded since beginning the study.

F2: After adjusting for length differences, SN females averaged 0.3% greater fecundity than HC females for broodyear 2002.

HC (mean=3677.8, 0.5% less than SN), SH (mean=3544.1, 4.1% less than SN), and SN (mean=3697.7).

Knudsen et al. submitted

Unpublished data: Knudsen. 2007.
| Egg weight (A9) | \(F_1\): After adjusting for broodyear and length differences when necessary, SN females had mean egg weight 1.5 mg heavier than SH females for broodyears 1997 through 2001.  
\(F_2\): Adjusted average egg weight of BY2003 HC (191 mg; \(n=30\)) and SH (198 mg; \(n=37\)) age 4 females were essentially equal with no significant difference (\(p=0.301\)). This is the same result we found for BY2002 age 4 females. | \(F_1\): After adjusting for broodyear and length differences when necessary, SN females had 0.8% heavier Mean Egg weight than SH females.  
\(F_2\): No significant difference between age 4 HC and SH females in either BY2002 and BY2003. | Knudsen et al. submitted  
|---|---|---|---|
| Reproductive effort (A10) | \(F_1\): No significant differences were detected between SH and SN females for broodyears 1997 through 2001.  
\(F_2\): Adjusted mean Reproductive Effort of HC (0.209; \(n=30\)), SH (0.207; \(n=37\)), and SN (0.205, \(n=188\)) origin age 4 females were statistically equal (\(p=0.320\)) for BY2003. Age 4 BY2002 females followed the same trend. | \(F_1\): No significant differences were detected between SH and SN females between broodyears 1997 and 2001. SH females had 0.8% greater reproductive effort on average than SN females.  
\(F_2\): No significant difference between HC, SH, and SN females in BY2002 and BY2003. | Knudsen et al. submitted  
| Male and female fertility (A11) | \(F_1\): Of the dead eggs we collected from the isolettes in 2004, 98% of the SH mortalities and 97% of the SN mortalities were not fertilized, respectively. Thus, the vast majority of both SH and SN dead eggs were due to not being fertilized and there was no significant difference. On average only 2- | \(F_1\): No significant difference. | Unpublished data |
3% of all eggs died after being fertilized. The majority of eggs (SH 76% and SN 86% in 2004) survived to the eyed egg stage. F2: These data have not been analyzed, yet.

<table>
<thead>
<tr>
<th>Adult morphology at spawning (A12)</th>
<th>Wild and F1 4-year olds were compared over BY1998-2000. Statistically significant shape differences for females: mean absolute value difference was 0.31 stdev, range 0.21 to 0.45; males mean 0.35 stdev, range 0.15-0.54</th>
<th>Statistically significant shape differences for females: mean 1.3%, range 0.8-2.5%; males mean 1.5%, range 0.4 – 3.2%</th>
<th>Busack et al. 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult spawning behavior (A13)</td>
<td>Marginally non-significant differences in female spawning behavior did occur in three cases. First, hatchery females had a slightly higher propensity to abandon their redds ($P = 0.059$). Second, more wild females spawned in the lowest parts of each section of the artificial stream—these areas closely resembled natural pool-riffle transition zones in natural streams ($P = 0.81$). And third, a greater percentage of wild females covered their eggs within one minute of spawning than did hatchery females (70% vs. 56% = 14% difference). Statistically significant differences were found in male agonism. Wild males had higher mean attack rates ($P = 0.01$) exhibited greater positive agonism ($P = 0.01$) and higher social dominance ($P = 0.02$) than hatchery males. No difference was seen in the frequency of courting behavior between the two types of males ($P = 0.16$). All of these behavioral traits were positively</td>
<td>Seventeen percent of the hatchery females placed into the artificial stream abandoned their redds while only 6.6% of the wild females exhibited this behavior for a 10.4% difference. Fifty-eight percent of the wild females spawned in the lowest parts of each section of the artificial stream. Only 43% of the hatchery females chose to spawn in these same areas for a 15% difference. Finally 70% percent of the wild females covered their eggs within one minute of spawning while only 56% of the hatchery females did so. On average wild males attacked other fish 0.45 times per min while hatchery fish attacked rivals 0.35 per min. Positive agonism or the ratio of attacks delivered to attacks received was 47.6% in wild males and 36.4% in hatchery males. Overall dominance in wild males averaged 31.2%</td>
<td>Schrodter et al. In Press, (Transactions of the American Fisheries Society) and Schrodter et al. submitted.</td>
</tr>
<tr>
<td>Adult spawning success (A 14)</td>
<td>No difference was found in the ability of naturally spawning hatchery and wild females to deposit their eggs. However, the eggs deposited by wild females achieved a 6% higher egg-to-fry survival rate than those deposited by hatchery origin females. Male breeding success was determined by estimating the number of fry each male fathered. Significant differences did exist among males on their ability to produce offspring but those differences were not linked to their origin (hatchery or wild)</td>
<td>Egg Deposition: Mean for wild females was 92.8% &amp; the mean for hatchery females was 90.4% a non-significant difference. Deposited egg-to-fry survival: Mean for wild females was 60.5%, mean for hatchery females was 53.2%. Hatchery and wild males mated with a similar number of females (3.6 for wild and 3.5 for hatchery males) and had comparable breeding success values (3.03% for wild and 2.64% for hatchery).</td>
<td>Schroder et al. <em>In Press</em>, &amp; Schroder et al. submitted.</td>
</tr>
<tr>
<td>Redd characteristics</td>
<td>Differences were not detected in characteristics of SH and SN redds for return year 2002-2005.</td>
<td>Differences were not detected in return years 2002-2005.</td>
<td>Knudsen et al. submitted</td>
</tr>
<tr>
<td><strong>Juvenile</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergence timing (J1)</td>
<td>F₁: We assumed that water temperatures did not vary between experimental vessels, since they were on a common water source. However from 2002 to 2006, it was found that water temperatures did vary significantly between monitored vessels even after efforts were made in 2006 to correct the problem. Valid comparisons of emergence timing are</td>
<td></td>
<td>Unpublished data</td>
</tr>
</tbody>
</table>
only possible if a method can be found to account for inter-vessel variation in water temperature. However, the variation is unknown for the vast majority of unmonitored vessels.

| **K_D at emergence (J2)** | **F_1**: K_D values of SH_p (overall mean = 1.98) and SN_p (overall mean=1.99) fry did not differ significantly ($P=0.126$) in a 2-way ANOVA testing for Origin and Brood year effects.  
F_2: ANCOVA of BY2006 indicated that K_D vs. Egg weight relationships of HC_p (n=27) and SN_p (n=26) fry were significantly different ($p=0.050$). A t-test comparing K_D HC_p (mean =1.968) and SN_p (mean=1.975) fry was not significant ($p=0.598$). | **F_1**: K_D values of SH_p origin fry were greater than SN_p fry by 0.5% on average. | Knudsen et al. in press. |
| --- | --- | --- | --- |

**Egg-fry survival (J3)** | **F_1**: In 2001, SN_p fry survived at a significantly higher rate than SH_p fry ($P=0.047$), while in 2004 SH_p fry had significantly higher survival ($P=0.023$). The other two broodyears were not significantly different (2002 and 2003, $P>0.41$). Thus, the effects of female origin on fry survival varied significantly across broodyears and showed no consistent trend.  
F_2: BY2002 - Egg-to-fry survival of SN_p fry (mean survival= 0.677) was approximately the same as HC_p fry (mean survival= 0.681). Origin effects were not significant (t-test) | **F_1**: No consistent trend over the period 2001-2004. | Knudsen et al. in press. |

<p>| <strong>Knudsen et al. in press.</strong> | <strong>Unpublished data: Knudsen 2007.</strong> | <strong>Unpublished data: Knudsen 2007.</strong> | <strong>Unpublished data: Knudsen 2007.</strong> |</p>
<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
</tr>
</thead>
</table>
| Fry-smolt survival in a hatchery environment | For SN BY97-05: Mean 0.928, stdev 0.062  
For HC BY02-05: Mean 0.954, stdev 0.064  
No analysis of stat. significance |
| Juvenile morphology at release (J6) | Preliminary analysis: CFlat SN and HC juveniles compared for BY02-04 (total of 392 fish). Analysis of partial warps based on all fish. MANOVA found significant year effects and origin x year interactions, but no origin effect. CDA classified 81% correctly to year, only 53% to origin. CDA by year classified 68%, 64%, and 53% correctly to origin for BY02,03,04 respectively. |
| Smolt-to-smolt survival (J7) | Hatchery-wild comparisons at Roza Dam are problematic because of different release dates. In 2007, most of the wild springHC smolts (2 raceways) survived 90% as well from Clark Flat to McNary Dam as SH smolts (4 raceways; \( p=0.031 \), 2-tailed \( t \) test). Cormack/Jolly-Seber survival rate estimates by raceway |

**Unpublished data**

- **Occurrence of developmental abnormalities (J4)**
  - F1: Occurrence of abnormalities in emergent fry were very low (<0.9%), for broodyears 1997 to 2000 and no significant SH and SN differences were observed.
  - F2: Analyses of BY2002 have not been completed, yet.

- **Unpublished data**
  - Source: Bosch CESRFSSurvStatswEggctCorrectionFactor.xls

- **Smolt-to-smolt survival (J7)**
  - HC smolts (2 raceways) survived 90% as well from Clark Flat to McNary Dam as SH smolts (4 raceways; \( p=0.031 \), 2-tailed \( t \) test). Cormack/Jolly-Seber survival rate estimates by raceway
<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>chinook smolt sample was captured at Roza Dam before the volitional</td>
<td>Preliminary survival rates from Clark Flat to McNary Dam in 2007 were 36.8% for SH smolts and 33.2% for HC smolts.</td>
<td>using PITPro 4.10 (P. Westhagen and J. Skalski, processed by D. Lind)</td>
</tr>
<tr>
<td>release date of March 15 for all hatchery groups. Preliminary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>survival rates from Clark Flat to McNary Dam in 2007 were 36.8% for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SH smolts and 33.2% for HC smolts.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural smolts produced per female spawner (J8)</td>
<td>This index depends on the application of reliable population assignment data to reliable outmigration data at Prosser. There are data gaps in both 2006 and 2007 counts due to high flows and unrelated canal repairs.</td>
<td></td>
</tr>
<tr>
<td>Smolt-to-adult survival of hatchery-origin fish (J9)</td>
<td>Analyses have not been completed</td>
<td>Analyses have not been completed</td>
</tr>
<tr>
<td>Smolt out-migration timing and rate (J10)</td>
<td>Hatchery-wild comparisons at Roza Dam are problematic because of different release dates. In 2007, most of the wild spring chinook smolt sample was captured</td>
<td>Travel times in 2007 for the HC group from volitional release at Clark Flat to Prosser and McNary were 91% and 94% of SH travel times. However, starting from acclimation site exit date instead of volitional release date, the HC group took 20% longer to reach Prosser and 34% longer to reach McNary than the SH group. In other words, the HC group left the acclimation site sooner than the SH group, but the SH group more than made up for this difference by migrating faster than the HC group.</td>
</tr>
<tr>
<td>Food</td>
<td>Preliminary analysis of SN and HC juveniles</td>
<td>Preliminary analysis indicates HC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unpublished; data</td>
</tr>
<tr>
<td>Conversion efficiency (J11)</td>
<td>at CESRF from ponding through December for 2002-2004. FCR estimated as pounds of fish/pound of food. HC and SN differed significantly (P=0.015); ls means: HC 0.759; SN 0.718.</td>
<td>Conversion was 5.75% higher than SN</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Juvenile length-weight relationships (J12)</td>
<td>F$_1$: ANCOVA analyses showed that SH$_p$ fry were significantly ($P=0.002$) heavier (mean body weight across all years = 317 mg) than SN$_p$ fry (mean body weight across all years = 313 mg) in each of the four years.</td>
<td>F$_1$: This indicated that, given eggs of the same weight, SH$_p$ fry will have ~1% greater body mass than SN$_p$ fry, which suggests that SH embryos were slightly more efficient in converting yolk to body mass.</td>
</tr>
<tr>
<td></td>
<td>F$_2$: We tested for Origin effects in BY2002 fry body weight distributions by ANCOVA using egg mass as a covariate. HC$_p$ fry (mean body weight = 300 mg) were slightly smaller than SN$_p$ fry (mean body weight 304 mg), but there was no significant Origin effect (p=0.209) indicating that, given eggs of the same weight, hatchery fry will have equivalent body mass as wild fry in 2006.</td>
<td>F$_2$: No significant difference in BY2002.</td>
</tr>
</tbody>
</table>
| Agonistic-competitive behavior (J13) – Contest | F$_1$: SN$_p$ fish initiated 0.05 more interactions/min and grew an average of 44.43 mg/week more than SH$_p$ in BY 02 and 03 combined.  
F$_2$: SH initiated 0.31 more interactions/min in BY 04 and 0.28 more interactions/min in BY 05 than WC. SH initiated 0.33 more interactions/min in BY 04, 0.26 less interactions/min in BY 05, and 0.01 (P>0.05) interactions/min in BY 06 than HC. SH lost an average of 99.3 mg/week less weight in | F$_1$: SH$_p$ fish were 6% (11%) less dominant (P=0.058), 3.8% (7.4%) less aggressive, and grew 36% (312%) less by weight than SN$_p$ fish in BY 02 and 03 combined.  
F$_2$: SH were 24% (39%) more dominant than WC in BY 04 and 05 and 20% (33%) more dominant than HC in BY 04 but 20% (50%) less dominant than HC in BY 05 and 6% (11%) (P>0.05) more dominant in BY 06. SH were 14% (24%) more aggressive than WC in BY 04 and 05 and were 14% | F$_1$: Pearsons et al. 2007a; b  
F$_2$: Pearsons et al. 2008 |
BY 04 and gained an average of 111.34 mg/week more in BY 05 than WC. SH lost an average of 43.43 mg/week less in BY 04, gained 57.88 mg/week less weight in BY 05, and gained 0.15 (P>0.05) mg/week more weight in BY 06 than HC.

(24%) more aggressive than HC in BY 04 but 14% (33%) less aggressive in BY 05 and 0.6% (1.1%) (P>0.05) less aggressive in BY 06. SH lost 46% (169%) less weight than WC in BY 04 and gained 34% (51%) more weight than WC in BY 05. SH lost 20% (53%) less weight than HC in BY 04, gained 22% (60%) (P>0.05) less weight than HC in BY 05, and gained 0.08% (0.2%) (P>0.05) more weight than HC in BY 06.

<table>
<thead>
<tr>
<th>Agonistic-competitive behavior (J13) - Scramble</th>
<th>F&lt;sub&gt;1&lt;/sub&gt;: SN&lt;sub&gt;p&lt;/sub&gt; fish initiated 0.07 more interactions/min and lost an average of 64.74 mg/week more weight than SH&lt;sub&gt;p&lt;/sub&gt; in BY 02 and 03 combined. F&lt;sub&gt;2&lt;/sub&gt;: SH initiated 0.45 fewer interactions/min and gained an average of 25.52 mg/week less weight than HC in BY 05. SH initiated 0.01 (P&gt;0.05) fewer interactions/min and lost an average of 15.16 (P&gt;0.05) mg/week less weight than HC in BY 06.</th>
<th>F&lt;sub&gt;1&lt;/sub&gt;: SH&lt;sub&gt;p&lt;/sub&gt; were 2% (4%) less dominant in BY 02 (P&gt;0.05) and 4% (8%) more dominant in BY 03 (P&gt;0.05) than SN&lt;sub&gt;p&lt;/sub&gt;. SH&lt;sub&gt;p&lt;/sub&gt; fish were 4.8% (9.2%) less aggressive, and lost 62% (76.6%) less weight than SN&lt;sub&gt;p&lt;/sub&gt; fish in BY 02 and 03 combined. F&lt;sub&gt;2&lt;/sub&gt;: SH were 17% (43.6%) less dominant than HC, 26% (69%) less aggressive, and grew 12% (25%) less by weight (P&gt;0.05) during BY 05. SH were 2% (4.3%) (P&gt;0.05) less dominant than HC, 0.6% (1.2%) (P&gt;0.05) less aggressive, and lost 3.2% (6.1%) (P&gt;0.05) less weight during BY 06.</th>
<th>F&lt;sub&gt;1&lt;/sub&gt;: Pearsons et al. 2007 F&lt;sub&gt;2&lt;/sub&gt;: Pearsons et al. 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator avoidance (J14)</td>
<td>F&lt;sub&gt;1&lt;/sub&gt;: Out of every 100, 2 fewer SH&lt;sub&gt;p&lt;/sub&gt; fry survived relative to SN&lt;sub&gt;p&lt;/sub&gt; in BY 02 and 03 combined. F&lt;sub&gt;2&lt;/sub&gt;: Out of every 100, 1.25 fewer HC fry survived relative to SH in BY 04 to 06 combined and 1.25 fewer HC fry survived</td>
<td>F&lt;sub&gt;1&lt;/sub&gt;: SH&lt;sub&gt;p&lt;/sub&gt; survival was 2% (3%) lower than SN&lt;sub&gt;p&lt;/sub&gt; after one generation (BY 02 and 03 combined). F&lt;sub&gt;2&lt;/sub&gt;: SH survival was 1.25% (1.8%) higher than HC (P&gt;0.05) during BY 04 to 06 and 0.2% (0.2%) lower than WC&lt;sub&gt;p&lt;/sub&gt; (P&gt;0.05) in</td>
<td>F&lt;sub&gt;1&lt;/sub&gt;: Fritts et al. 2007 F&lt;sub&gt;2&lt;/sub&gt;: Pearsons et al. 2008</td>
</tr>
</tbody>
</table>
| Incidence of precocious maturation in production raceways (J15) | BY 2002 $S_{H_p-SN_p} = -32\%$
BY 2003 $S_{H_p-SN_p} = -12\%$
BY 2004 $S_{H_p-SN_p} = -14\%$
BY 2005 $S_{H_p-SN_p} = -29\%$ | Incidences of precocity in progeny of SH are reduced by more than 50% due to one generation of hatchery culture. | Mean precocity rates of male progeny (Clark Flats) from first generation hatchery parents were 14% (brood year 2002), 11% (brood year 2003), 14% (brood year 2004) and 22% (brood year 2005). Mean precocity rates of male progeny for natural origin parents were 46% (brood year 2002), 23% (brood year 2003) and 28% (brood year 2004) and 25% (brood year 2005). These data are collected as part of BPA contract # 200203100 "Growth modulation in salmon supplementation". |