

**DESIGN, OPERATION AND MONITORING OF A
PRODUCTION SCALE SUPPLEMENTATION
RESEARCH FACILITY**

David Fast
Yakama Nation Fisheries
P.O. Box 151 Toppenish, WA 98948
509-966-5291 (ph) / 509-966-7406 (fax) / fast@yakama.com

Abstract: The Yakima/Klickitat Fisheries Program (YKFP) has designed a supplementation program to enhance the spring chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima Basin. The purpose of the YKFP is to test the assumption that new artificial production can be used to increase harvest and natural production 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.

This paper describes the design and operation of a production scale supplementation facility from broodstock collection protocols, through the factorial mating schemes, incubation, rearing experiments, and volitional release of 810,000 smolts from three acclimation sites. The experimental design includes testing new Semi-Natural rearing Treatments (SNT) against the Optimum Conventional Treatments (OCT) of existing successful hatcheries in the Pacific Northwest. Monitoring efforts are directed at evaluation of the performance of supplementation fish in each of the following categories, and comparison with the performance of naturally reared fish.

1. The post-release survival of supplementation fish (both outmigrating smolts and returning adults).
2. The homing and reproductive success of supplemented populations.
3. The long-term fitness of supplemented populations.
4. The inter- and intra-specific interactions (including competition, predation and genetic effects) between supplemented and unsupplemented populations.

Information resulting from this research can be used by resource managers to improve the survival and performance of hatchery reared salmonids. This information is posted to the project website ykfp.org.

Introduction

Historically, numbers of anadromous fish returning to the Yakima River were estimated to have ranged from 600,000 to 960,000 per year (BPA, 1990). Current salmonid runs (five year average 1997-2001) in the Yakima River have been reduced to fewer than 18,600 adults (less than 3% of the historical run size).

In an attempt to reverse this trend the Northwest Power Planning Council (NPPC) in 1982 first encouraged Bonneville Power Administration (BPA) to “fund the design, construction, operation, and maintenance of a hatchery to enhance the fishery for the Yakima Indian Nation as well as all other harvesters.” (NPPC, 1982). In 1990 a Preliminary Design Report indicated that production facilities could be built in the Yakima River Basin to supplement natural production, provide harvest benefits, and gain knowledge about supplementation techniques of benefit to the entire region (BPA, 1990). Thus the Yakima Klickitat Fisheries Program (YKFP) had evolved from a harvest enhancement effort into a full production supplementation and research program. The YKFP is co-managed by the Yakama Nation and the Washington Department of Fish and Wildlife (WDFW) with the Yakama Nation as the lead entity.

Recent reviews of artificial propagation in the Columbia Basin (NMFS, 1999; ISAB, 2000) have documented several practices (e.g., out-of-basin stock transfers, unrepresentative broodstock collection practices, etc.) that make certain hatchery populations undesirable for integration with wild populations. The YKFP was designed to implement and evaluate the risk avoidance guidelines as outlined by Ford (1999) and others.

Planning and Design

The purpose of the YKFP is to test the assumption that new artificial production can be used to increase harvest and natural production 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. Spring chinook salmon (*Oncorhynchus tshawytscha*) was selected as the species for this research. Three genetically distinguishable populations of spring chinook salmon exist in the Yakima subbasin (Figure 1): the American River, the Naches, and the Upper Yakima Stocks. The upper Yakima was selected as the population best suited for this research effort.

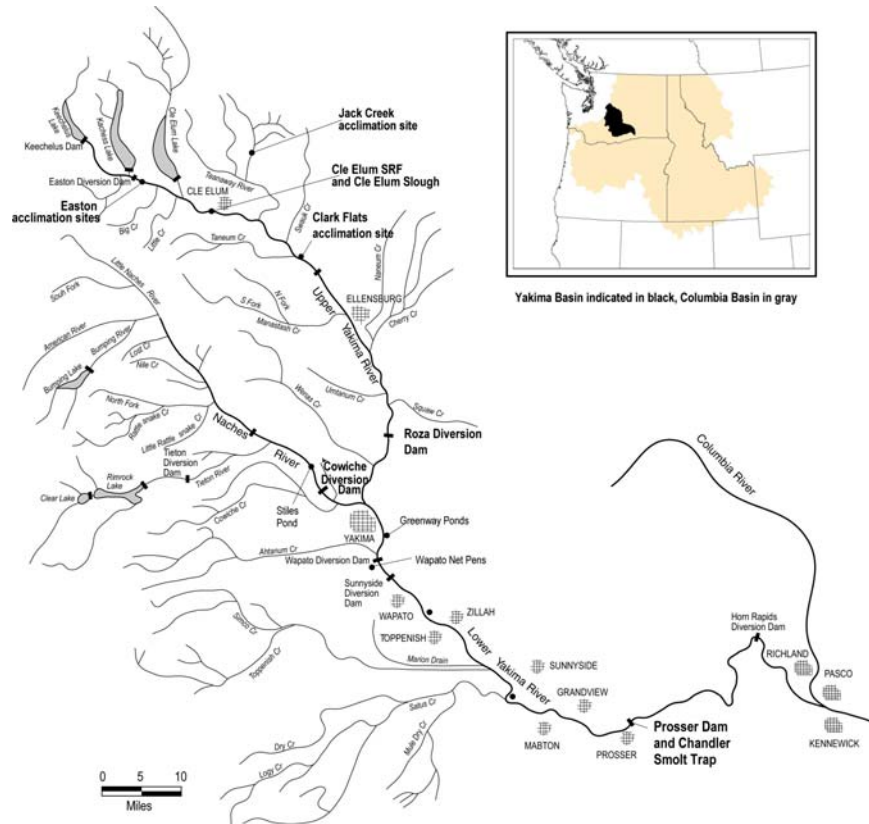


Figure 1. Yakima River Basin.

Much of the material presented in the following section is excerpted from the Biological Specifications for Facility Design Report (Hager et al., 1998).

Facilities were designed and constructed in the Upper Yakima River Basin to serve as a production scale laboratory to resolve critical uncertainties related to supplementation. Scientists are using this laboratory to evaluate the alternative fish culture techniques that can be used in supplementation programs. These evaluations are expected to generate improved fish culture and release techniques.

The main value of the scientific information obtained from this facility over the next several decades is its adaptive management application to other programs within the Columbia River Basin. Therefore, the biological specifications required that certain aspects of the facilities (e.g., raceways) be designed in common with existing hatcheries. This will allow concepts that are successful to be retrofitted to existing facilities.

Adult Collection and Monitoring

The upper Yakima population was composed of wild spring chinook. Project scientists designed the program to minimize the genetic divergence from the wild parent population and to maintain long-term adaptive traits. Roza dam is an impassable fish barrier (Figure 1). All fish migrating into the upper Yakima must pass through the adult monitoring and broodstock collection facility. Following Genetic Hatchery Guidelines (GHG), only naturally produced (non-marked) fish will be selected for hatchery use and no more than 50% of the available non-hatchery fish can be used for broodstock (Kapusinski and Miller, 1993; YKFP, 1995). Thus, at least 50 % of the returning adults will be allowed to spawn in the wild. Broodstock are selected throughout the duration of the adult run. The adult population is sampled such that the collected adults represent population parameters including arrival time, age, size, etc. All broodstock collected at Roza Dam are PIT tagged, photographed, and transported to Cle Elum Hatchery by truck on the day of capture.

Biological specifications estimated that a maximum of 1,110 Upper Yakima spring chinook salmon adults would be collected for spawning retention. The assumptions used to derive the preliminary estimate of the numbers of broodstock were: egg to smolt survival - 65%, adult mortality - 20%, and eggs per female – 3,500.

Adult holding success is dependent upon water quality. Water quality must be sufficient for adult holding in terms of water chemistry, pathogens, and temperature. The recommended adult salmon holding temperature range is 43°F (Leitritz and Lewis, 1980) to 55°F (Piper et al., 1982). The design planned for the availability of pathogen-free groundwater to enhance adult holding by reducing mortality.

Several diseases occur in adult salmon and will probably occur in fish held for broodstock. Standard fish health protocols are planned for these occurrences.

Spawning/Mating

Broodstock are reared to maturity on a schedule similar to wild fish, with spawning from early September into October. Mature fish are taken from the adult holding area, identified by PIT tags, photographed, and spawned. Eggs and sperm (milt) from individual spawners are placed in separate containers.

Mating is randomized with respect to phenotypic traits, including size, within each group of adults that are ripe on the day of spawning. A factorial mating scheme is used with each female's eggs divided into several lots. Each lot is fertilized with the sperm from a different male. After fertilization, the egg lots are combined for incubation. Each female's eggs are later divided into two equal lots for experimental treatment and control groups.

Spawned carcasses are sampled for DNA analysis, frozen, and placed in the stream for nutrient enhancement.

Isolation-buckets (Novotny et al., 1984) and vertical incubators (Senn et al., 1984) are used to incubate spring chinook salmon eggs at the Cle Elum Hatchery. Wells provide pathogen-free water for incubation. Eggs are isolated from fertilization through the eyed stage to allow for disease certification.

Hatchery Rearing Experimental Design

The biological specifications define facilities in which two experimental treatments can occur. To maximize experimental flexibility, statistical power, and facilitate fish handling the biological specifications planned for at least nine vessels per treatment from incubation through rearing and acclimation.

The project experimental design requires that each experiment be conducted over one life cycle. With spring chinook salmon, the facility is dedicated to comparing treatment effects over five year blocks. The first five-year block compares the effectiveness of conventional rearing methods and semi-natural rearing methods for producing smolts suitable for supplementation programs. The two treatments to be applied are Optimal Conventional Treatment (OCT) and Semi-Natural Treatment (SNT). Experimental treatments are applied at the start of feeding and continued until the smolts leave the acclimation ponds.

The Optimal Conventional Treatment is the experimental control that uses state-of-the-art artificial production techniques in incubation, rearing, and acclimation to raise and release fish. The Semi-Natural Treatment is an experimental

treatment that creates a more natural environment to rear and acclimate fish. The intent of this treatment is to raise and release fish that mimic the positive survival characteristics and behavior of their naturally produced counterparts.

Production Objective: The experimental design requires the production of 810,000 fish in 18 separate lots of 45,000 smolts for release as experimental groups into the watershed above Roza Dam. These fish will be 15 per pound at release.

Optimal Conventional Treatment

The production population is separated into 18 groups, nine of which are reared under the Optimal Conventional Treatment and nine as the Semi-Natural Treatment (Hoffman et al., 1995). The OCT fish are reared under conditions in the hatchery and at off-site acclimation ponds that are expected to produce the highest quality and most fit hatchery fish. Density, flow and temperature criteria guidelines are:

- The maximum rearing density is 0.75 lb/ft³ of rearing space.
- Flow is provided to maintain a high level of dissolved oxygen (not less than 7 ppm) at the outflow. Raceways are supplied with 1.44 cfs (650 gpm) through a pond-width manifold.
- Two water supplies are required for the culture of spring chinook salmon at Cle Elum Hatchery: (1) a production quantity surface water source to provide a fluctuating environment (water quality and temperature) needed to properly induce smoltification, and (2) a groundwater system to maintain design temperature maximum of 55°F during the summer.

By definition, OCT rearing vessels represent the current Pacific salmon production standards in length, width, depth, and inflow. Raceway vessels typically conform to a ratio of 30:3:1 for length, width, and depth, respectively (Piper et al., 1982). The experimental design assumes a raceway standard of 100' x 10' x 3.5' (operating depth) as the optimal conventional treatment.

Semi-Natural Treatment

The Semi-Natural Treatment is consistent with the criteria for density, flow, temperature and raceway design of the Optimum Conventional Treatment. This treatment is designed to test the hypothesis that a more natural environment will increase post-release survival by developing cryptic coloration, feeding and hiding behaviors that increase post-release survival.. This rearing environment is designed to include:

- camouflage painted surfaces to enhance more natural coloration
- overhead cover for shade and hiding
- instream cover for hiding, and
- underwater feeders to encourage feeding away from the surface where exposure to avian and fish predators is increased.

All of the juveniles are marked with coded wire tags that identify their raceway and treatment group. Approximately ten percent of the juveniles also receive a Passive Integrated Transponder (PIT) tag.

Acclimation Rearing

Prior to the end of their rearing cycle (approximately one year post swim-up), all experimental groups are transferred to off-site rearing ponds for acclimation and release. This transfer occurs in late January or early February depending upon snow conditions.

Following the experimental design (Hoffman et al., 1995), three acclimation sites with six raceways per site were constructed. One site is located at Easton, on the upper mainstem above the Cle Elum facility, one at Clark Flats on the Yakima River below Cle Elum, and one at Jack Creek on the Teanaway, a tributary that enters the Yakima River below Cle Elum (Figure 1). These sites were selected because they are located in historical spring chinook spawning areas, and they also allow research on imprinting, homing and straying.

Each acclimation raceway is sized to hold an OCT or SNT treatment group of 45,000 spring chinook smolts. Fish are held in the raceways until March 15th when they are volitionally released. Smolts exiting from the raceways migrate through a PIT tag detector and enter the stream. Acclimation sites are operated through May 31, when the water is turned off. Returning adults are expected to spawn in the adjacent stream.

By the end of the hatchery rearing cycle, acclimated fish are expected to have attained their maximum size of fifteen fish per pound (15 fpp). The planned size at release is within the range of release size criteria common throughout the region (Hopley, 1993).

Implementation and Operation

The YKFP began implementation of the spring chinook supplementation program in 1997 with the collection of broodstock at Roza dam. The broodstock collection criteria described in the previous section were followed with random collection of adults throughout the spawning run (Figure 2).

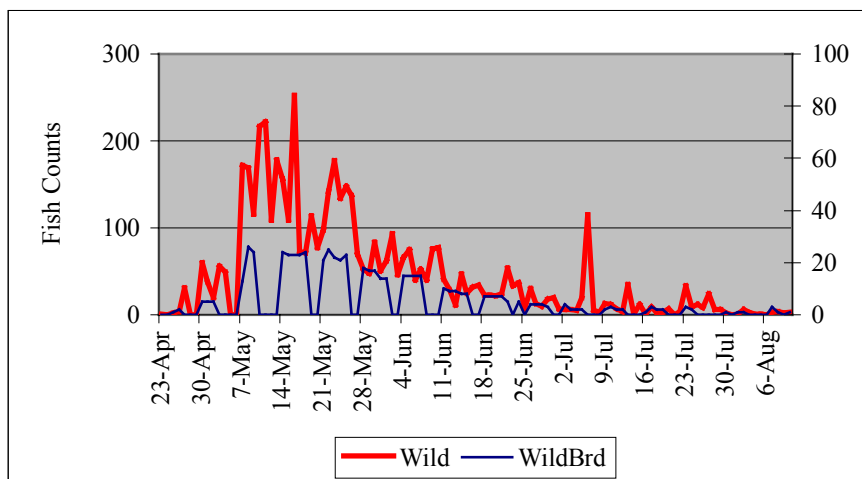


Figure 2. Wild adult spring chinook salmon run timing at Roza dam with broodstock collection timing for 2001.

Table 1 presents the wild adult run size at Roza dam for the years 1997 through 2001, with the total number and percentage of wild fish collected for broodstock. With a very low run of 795 adults in 1998, the program took 408 adults into the hatchery and exceeded its 50% criteria (adult spawners in the wild) by 1.3%. In all other years the percent collected was below 50%, with only 4.9% of returning adults collected in 2000.

Table 1. Upper Yakima Spring Chinook wild returns and broodstock collection at Roza Dam, 1997-2001.

Year	Wild		Collection Percentage
	Wild fish At Roza	broodstock collections	
1997	1,445	261	18.1%
1998	795	408	51.3%
1999	1,704	738	43.3%
2000	11,639	567	4.9%
2001	5,346	595	11.1%

Broodstock collection numbers in 1997 were reduced because the construction of the Cle Elum facility was somewhat behind schedule. A total of 261 adults were collected with the plan to use six raceways (three OCT and three SNT, and one acclimation site) to test the facility (Table 1). Due to the lower than expected adult mortality, higher fecundity, and higher than expected egg to smolt survival, a total of 10 raceways (386,048 smolts) were produced (Table 2).

Table 2. CESRF Spring Chinook Releases for Brood Years 1997-2000.

Brood Year	OCT Releases	SNT Releases	Total Releases
1997	207,437	178,611	386,048
1998	284,673	305,010	589,683
1999	384,563	374,226	758,789
2000	424,604	409,768	834,372

Spawning, rearing and release operations have followed the design criteria described in the previous section. The numbers of broodstock collected in 1997 and 1998 were below full production criteria due to testing the facility in 1997, and low wild run size in 1998. The 1999 and 2000 broodstock collections produced 758,789 and 834,372 smolts respectively, approximating the full production goal of 810,000 smolts (Tables 1 and 2).

Operation of the acclimation facilities followed the design criteria. Outmigration timing of volitionally released smolts from the acclimation facilities was similar to the timing of wild smolts at Chandler Juvenile monitoring facility (Figure 3). Wild smolts begin their outmigration earlier due

to the supplementation smolts being held at acclimation sites until March 15. Timing of outmigration for both wild and supplemented smolts past Chandler appears to be triggered by an increase in flow.

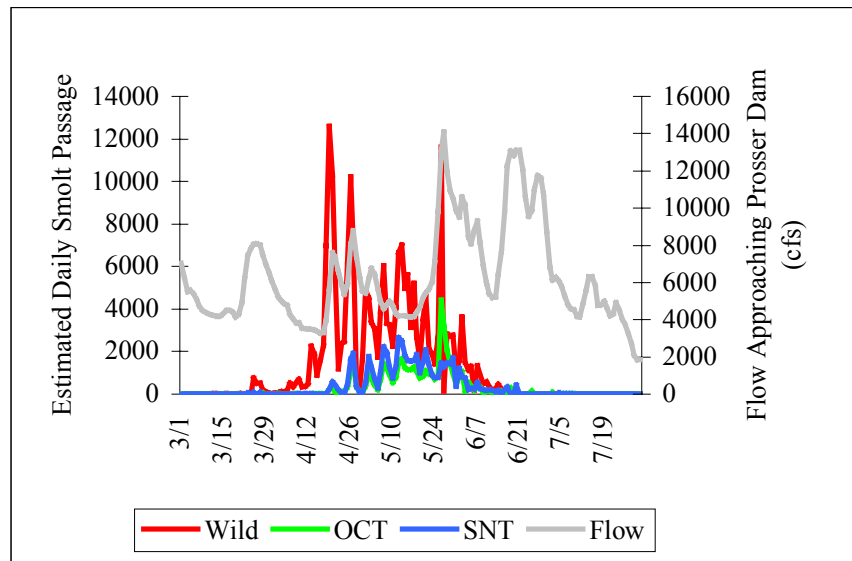


Figure 3. Wild and Hatchery Spring Chinook Smolt Passage Timing at Chandler Juvenile Facility, 1999.

Monitoring and Evaluation

The success of a supplementation program depends upon two factors. First, the program must return more adults than would have been produced in the wild by allowing the fish to spawn naturally. Second, the returning fish must reproduce successfully to increase the productivity of the natural population. In addition to these objectives, the project has stated that it should maintain the long-term genetic fitness of the fish population being supplemented, and keep the adverse genetic and ecological interactions with non-target species or stocks within acceptable limits.

Monitoring efforts are directed at evaluation of the performance of supplementation fish in each of the following categories, and comparison with the performance of naturally reared fish (Busack et al., 1997).

1. *The post-release survival of supplementation fish (both outmigrating smolts and returning adults).* All of the smolts released from the supplementation program are coded wire tagged to identify treatment group, acclimation site and pond. Approximately ten percent of the smolts are also PIT tagged for non-lethal monitoring of OCT and SNT treatment groups as they migrate out of the Yakima and Columbia. Wild smolts are also PIT tagged at Roza dam to allow comparison of their survival to the OCT and SNT groups. These PIT tags are monitored at Chandler Dam on the Yakima, and at McNary, John Day, and Bonneville Dams on the Columbia River. This outmigration survival data has been collected for the 1999 through 2001 smolt migrations. This completes three years of the five year monitoring cycle. The results of this smolt survival research will be published when the data from all five years has been collected and analyzed. This year (2002) marks the first complete return of three, four and five year old adults. All returning supplementation adults are scanned for coded wire and PIT tags at the Roza facility. Coded Wire tags are also collected from carcasses on spawning ground surveys. The adult survival research will also be published when sufficient data has been collected.
2. *The homing and reproductive success of supplemented populations.* The homing research is being conducted in conjunction with scientists from the National Marine Fisheries Service. As described above, all of the smolts are coded wire tagged to identify treatment, acclimation site and pond. Carcasses of spawned fish are sampled on the spawning grounds to determine their acclimation release site. The design of the project, with one acclimation site on the mainstem above the Cle Elum facility, one on the mainstem below it, and one located on a tributary that enters the Yakima River below Cle Elum, allows for a thorough analysis of imprinting and homing.

Scientists from WDFW have developed an experimental design for conducting reproductive success research. Both laboratory and spawning channel experiments are being conducted. Measurements of fecundity, eggs size, and sperm and egg viability of returning supplementation and wild fish are being made. In addition, an artificial spawning channel was constructed in 2000 to allow spawning to occur in a semi-natural stream. Wild and

supplementation adults can be placed in the stream and observations of behaviors such as female competition for spawning sites and male competition for females can be recorded. DNA samples are taken from all adults placed in the channel. Emerging fry are sampled and their DNA is analyzed to determine parentage. The reproductive success of individual adults can be determined from this study.

3. *The long-term fitness of supplemented populations.* An experimental design has been developed by geneticists with WDFW to monitor the long-term genetic performance of the supplementation program.
4. *The inter- and intra-specific interactions (including competition, predation and genetic effects) between supplemented and unsupplemented populations.* WDFW has been monitoring the interactions (competition, predation, etc) between the released supplementation fish and naturally produced populations of anadromous and resident species.

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