Using semi-natural rearing habitat to improve smolt-to-adult survival of chinook salmon.

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Final Report for IAC Contract 01-044
December 14, 2005

II. Abstract

In the first of a three-year study, artificial structures were added to a rearing pond of chinook salmon (*Oncorhynchus tschawytscha*) at Clear Creek Hatchery to determine if these structures improve smolt-to-adult survival. Floating and submerged structures covered 30% of the surface area of the treatment pond. Chinook reared in an identical pond without artificial structures were used to compare the effects of this treatment to the normal rearing practices at Clear Creek Hatchery. Chinook fry were placed into each pond in February 2001 and released volitionally as smolts in May 2001. Fish in each pond were raised using the same feeding regimes, and both ponds were covered with netting to avert predation. Three main structure types were used: PVC rings covered with camouflage netting, rectangular plastic lattice skirted with camouflage netting, and plain plastic lattice. These designs were chosen based on their being moveable, easy to clean, and having a low risk of disease transmission. Growth rates and overall health condition showed no significant difference between the two treatments. Coloration was significantly different between fish in the two ponds, with the fish in the treatment pond tending to be more intense. Ninety-two thousand chinook from each pond were marked with coded-wire tags to compare the smolt-to-adult survival of fish reared in each pond. The final results will be available in 2008.

III. Executive Summary

Clear Creek Hatchery is on the Nisqually River and is operated by the Nisqually Tribe. The main focus of the hatchery is to produce chinook to provide a sport and tribal fishery on the returning adults. Mainly because of habitat degradation, the chinook run has declined over the past several years, and the hatchery is turning its focus to recovering this population, with a longer term goal of providing fish for tribal harvest. In their recovery program for chinook, the Nisqually Tribe recommends the use of Natures rearing to increase the smolt-to-adult survival, and thereby improve the prospects for recovery. However, Natures rearing systems are untested for large-scale hatchery production, and while it has been established that Natures rearing can markedly increase the survival of out-migrating smolts immediately after release, there is no evidence that it will improve the long-term survival. In this project, we begin to test the hypothesis that the use of Natures rearing will improve the smolt-to-adult survival of chinook salmon.

Two large concrete rearing ponds were used in this experiment. We placed floating and submerged artificial structures in one rearing pond (the Natures pond) and the second pond was left without structures to represent the normal rearing practices at Clear Creek Hatchery. Structures in the Natures pond provided approximately 30% cover for the fish. Both ponds were the same size (190'X70'X4'), situated adjacent to each other, had the same water source, and were covered with netting to avert predation. Chinook in both ponds were fed the same diet, at the same rate, and were stocked at similar densities (687,000 chinook in NATURES pond, 674,000 chinook in control pond). A different coded-wire tag group was used for each rearing pond, and we tagged over 92,000 fish per pond. Chinook were raised in the rearing ponds from February 2001 until their volitional release in May 2001.

We tested a variety of structures for the Natures pond having the following criteria: 1) the structures had to be easy to clean and maintain, with a low risk of disease development; 2) they had to be easy to move so that the ponds could be cleaned during the rearing period; 3) the structures had to be used by the fish; 4) the materials had to be colors that occur naturally in the environment. Based on these criteria, we initially constructed a large variety of structures from a variety of materials, and tested all of them in the ponds. Within the first month after putting them in, visual observations indicated which structures were not being used, experience working the ponds indicated which structures were difficult to clean or move, and which structures seemed to create a risk to fish health (i.e. fish getting caught and dying on them). These structures were removed from the pond, leaving three structures that provided about 90% of the total cover used for the fish: 1) plastic rings covered with camouflage netting; 2) green or brown plastic lattice in 4'X8' sheets; and 3) green or brown plastic lattice skirted with camouflage netting.

Each month, we compared the growth of chinook in the two ponds, and observed little difference. Monthly fish health inspections revealed that the fish were “generally healthy and in good condition”. To evaluate whether the different environment created by the addition of structures affected the color of the fish, we took pictures of the caudal fin against a standardized blue background on three occasions. These tests revealed some differences in the coloration, but their significance to smolt survival is unknown.

This project will be repeated over the next two years (2002 and 2003 releases). From 2004 through 2008, we will track returns of adult chinook back to Clear Creek Hatchery. Tag returns from the different treatment groups will be compared to determine if addition of artificial structures increases smolt-to-adult survival of chinook.

IV. Purpose

A. Problem

For several years, experiments have shown that the addition of semi-natural habitat to raceways (Natures) can improve the short-term post-release survival of juvenile salmonids. Few experiments have tested aspects of these rearing strategies on a large-scale production basis, or evaluated the effects of Natures rearing on the production of additional adults. Pending the results of Natures experiments, the Nisqually Tribe is committed to adopting elements of Natures in their supplementation plan for recovering chinook. This project will assist with that evaluation. Another important aspect of this study is to ensure that the addition of semi-natural habitat to rearing ponds can be incorporated into the rearing activities at a hatchery without adversely affecting fish health. Improvements in survival could reduce the number of wild adults that must be taken into fish culture programs to produce a given number of recruits in the next generation, improve the success of supplementation programs in rebuilding self-sustaining runs, and reduce the number of fish that must be released from a given hatchery to provide the desired number of adults.

B. Objectives of the project.

Objective 1: Construct artificial floating and bottom structures from materials that can be cleaned and disinfected.
Objective 2: Compare growth of chinook salmon reared using conventional methods to those reared with the artificial habitat.
Objective 3: Compare the health of chinook salmon reared using the artificial rearing habitat to the health of fish reared using conventional methods.
Objective 4: Compare the coloration of chinook salmon reared using the artificial rearing habitat to the coloration of fish reared using conventional methods.
Objective 5: Compare the smolt-to-adult survival of chinook salmon reared using the artificial rearing habitat to that of fish reared using conventional methods.

V. Approach

A. Detailed description of the work that was performed.

From July through December, 2001 we built or purchased artificial structures to cover about 30% or the surface area of the Natures pond (Figure 1). Materials included PVC piping, plastic lattice, camouflage netting, plastic baskets, wood logs, and other plastics. Most of the structures were one of the following: 1) camouflage netting attached to circular rings of plastic pipe (circle sizes ranged from 3 - 6 feet in diameter, Figure 2 (C)); 2) brown and green plastic lattice, 4' X 8' rectangles, skirted with camouflage netting (Figure 2 (B)); or 3) brown and green plastic lattice, 4' X 8' rectangles, without camouflage netting (Figure 2 (A)). Other structures included an artificial floating “reef” constructed of laundry baskets (Figure 2 (F)), PVC structures resembling trees (Figures 4 and 5), and larger structures built from PVC and plastic lattice (Figure 2 (D)). Commercially-available products that we purchased included a fish sphere (Natural Habitats Unlimited, Inc.; Figure 2 (E)); Aquamats® (Meridian Aquatic Technology; Figure 3), and ElWd logs (ElWd Systems; Figure 2 (G)).

Clear Creek Hatchery has two identical, adjacent rearing ponds that were used in this experiment. The ponds are about 25 feet apart, and are 190 feet long, 70 feet wide and 4 feet deep. The bottoms are concrete and both ponds were covered with netting to avert predators. The water source was the same for both ponds, and was single pass well water. The ponds are cleaned by vacuuming, approximately once every two weeks. Fish are released from these ponds by removing the screens at the end of the pond. The fish swim through a pipe to Clear Creek, which merges with the Nisqually River about 0.5 mi downstream from the hatchery. Clear Creek is at river mile 6.6 on the Nisqually River which flows into Puget Sound just north of Olympia.

At Clear Creek Hatchery, chinook salmon are moved from the hatchery building to raceways while the fish begin feeding. After about a month, they are moved into the large ponds and reared there until release. Chinook from the 2000 brood were reared in raceways from first ponding in December 2000 through January 2001. We then set up the Natures pond, and on February 9th and 12th, 678,000 chinook fry were placed into the NATURES pond and 674,000 were placed into the control pond. Immediately before transfer, we measured the fork lengths of 500 fish in each group and recorded the average number of fish per pound. Initially, due to their small size, fish were placed in the upper third of each rearing pond and twice a day with BioDry 1000. Feeding was reduced to once per day as the fish grew larger. Feeding rates between groups was the same.

To enable hatchery personnel to effectively clean and move the artificial structures, we attached the structures to ropes and arranged them in rows across the width of the Natures rearing pond before the fish were put into the pond (Figure 1). Using this setup, hatchery personnel could move structures with minimal effort by untying the rope and pulling the structures to a new location where they could be tied off once more. Initially, a diversity of structures were placed in the ponds; however, it became apparent that some structures provided fewer cover or structural benefits and took longer to clean than other structures. We removed these structures. The commercially-produced fish sphere (Figure 1(E)) and Aquamats® (Figure 3) fit into this category, as did the PVC trees and logs we constructed (Figures 4 & 5). Other structures were perceived as a health risk to fish: hatchery personnel observed significant fish mortality on ElWd logs (Figure 1(G)) placed in the pond; fish leapt onto the wood and were unable to return to the water. Additionally, as a result of observations with an underwater camera, fish crates constructed from small-holed plastic lattice (approximately 1" square holes, Figure 1(D)) were not being used by nearly as many fish as other structures and were removed from the pond.

In March 2001, we coded-wire tagged 188,600 chinook from the treatment pond and 204,000 fish from the control pond. After tagging, the fish were given access to the entire area of each rearing pond. Additional structures were added to the Natures pond through April to increase surface area coverage to 30%.

From December 2000 through May 2001, a fish pathologist conducted monthly fish health inspections of the project fish. Additionally, in March and May, the pathologist conducted autopsies of 60 fish from each treatment group to complete a fish health assessment based on procedures outlined by Goede (1993). For each treatment group, the condition of the fins, opercles, eyes, gills, pseudobranchs, and thymus were recorded. The condition of the mesenteric fat, spleen, hind gut, kidney, liver, and bile was also assessed. We extracted blood from the caudal vein and measured the levels of hematocrit for each fish. The first blood samples, drawn in March, were too small to measure leukocrit and percent protein and we could not sex the fish. In May, there was enough blood to measure percent protein, which we did using a refractometer.

Once per month, we used a remote Sony underwater video camera to film the activities of fish under the Natures structures to obtain qualitative observations of fish use. Before filming under each structure, the camera was placed in the water and let sit for 15 - 30 min so that the fish activities would return to normal after being disturbed by the insertion of the camera. Filmed footage of fish activities ranged from 15 to 30 min per structure. We observed fish activity from this footage and noted any gross qualitative differences of fish densities that occurred among structures. Based on these observations, we modified additional structures in an attempt to maximize fish use of in-pond artificial structure.

Beginning in March, we photographed 60 fish from each rearing pond once per month to evaluate whether their coloration is affected by the addition of pond structures. We used ASA 400 color slide film in a Nikon 8000S single lens reflex camera equipped with a micro lens (60 mm) and circular polarizing filter. We placed the camera on a photographic stand equipped with two quartz halogen lamps (300 W) filtered through photographic gel to simulate daylight. We prepared the fish for color sampling by placing them in black buckets for at least 15 min. Next, we anesthetized the fish using MS222 and placed them on a clear acrylic stand positioned over a blue background. Along with the fish on the acrylic stand, we placed a label describing the date, fish number, and treatment pond. As a final step we took a picture of the fish and label. Each photograph was mounted into a standard plastic slide mount and placed on a PVC plate attached to the stage of a stereoscopic binocular. A fiber optic light illuminated each slide; we used a Hyper HAD RGB color video camera to transfer these images to analysis software (Image Pro Plus). Using this analysis software, a color comparison was completed of standardized rectangular sections of skin on the caudal fin. Measurements of hue, saturation, and intensity were the coloration factors compared for each treatment group.

On May 8, 2001, fish were allowed to begin a volitional release from both ponds. Fish out-migrated from the ponds for the next two weeks. During the third week, approximately 20,000 fish were left in each pond; these were pushed out so all chinook had left by May 25, 2001.

B. Project management: individuals and/or organizations performing the work and how it was done.

This project was a cooperative study conducted by Washington Department of Fish and Wildlife and the Nisqually Tribe. The National Marine Fisheries Service (working with an employee of the Pacific States Marine Fisheries Commission) collected and analyzed the color comparison data.

Participation occurred within each organization as follows:

Washington Department of Fish and Wildlife
Geraldine Vander Haegen; Fish and Wildlife Biologist 4. Project lead. Supervised and made recommendations to project operating procedures; edited reports.
Anita Swanson; Fish and Wildlife Biologist 2. Collected and analyzed data,, coordinated with organization staff.

Nisqually Tribe
Bill St. Jean; Chief Enhancement Biologist. Provided on-site oversight of project.
Al Barney; Enhancement Biologist. Worked with additional hatchery personnel/volunteers to construct artificial structures.

Northwest Indian Fisheries Commission
Jim Bertolini; Fish Pathologist. Conducted monthly fish health inspections and autopsies of fish for health assessment.

National Marine Fisheries Service:
Des Maynard; Research Scientist. Cooperator- provided underwater video camera.

Pacific States Marine Fisheries Commission
Gail McDowell; Fisheries Research Biologist. Performed color sampling and statistical analysis of color samples.

VI. Findings

A. Actual accomplishments and findings.

As described above, we successfully constructed and installed a number of pond structures and found many of them to be workable in a hatchery environment. Overall, we noted that the commercially available products we tested performed poorly, particularly in comparison to their cost. The simplest structures were most acceptable to the fish, and to the hatchery operations.

Growth Rate

From February through May 2001, chinook in the control group and Natures group grew at similar rates (Figure 7). When the fish were initially placed in the rearing ponds, fork lengths of the Natures and control groups were 52.8 mm and 51.5 mm, respectively. Average differences between fork lengths of the two treatment groups ranged from 0.8 mm - 1.9 mm. These differences were less than 3% of the average fork length of either group; from a biological standpoint, we determined this was not a significant difference. At release in May, average length of fish from the control group was 82.9 mm, and the Natures group was 84.8 mm.

Health Monitoring

While still in raceways (December - beginning February), chinook fry had normal mortality rates of <0.001%/day. In December, after their placement in the raceways, chinook in two of the raceways were diagnosed with coldwater disease (caused by *Flavobacterium psychrophilium)* and coagulated yolk syndrome (cause unknown). Subsequently, chinook in all the raceways were observed with these problems at a low level and affected fish died. By the next health inspection at the end of January, the pathologist described fish as being “generally healthy and in very good condition.” There was low prevalence of fin erosion and coldwater disease.

In February and April, the pathologist inspected fish in both rearing ponds and reported them to be in healthy condition. In April, from a very small sample of fish taken (6 from each pond), 2 of the Natures pond fish and none of the fish in the control pond were observed with *Trichophrya sp.*, a commensal organism, on their gills. In May, the pathologist conducted a pre-release exam on the chinook. Fish within the control pond were observed with an elevated mortality rate of approximately 0.02%/day, whereas fish in the Natures pond had normal mortality levels of <0.001%/day. Out of 10 fish examined from each pond, all of the fish from the control pond and nine from the Natures pond were observed with *Trichophrya sp.* on their gills. Additionally, one fish of the ten sampled from the control pond had early stages of bacterial kidney disease (BKD). The pathologist examined three additional dead fish from the control pond; all of them had advanced BKD. As a result of this and additional lab samples, the pathologist concluded that the elevated mortality observed in the control pond was a result of BKD.

Initially, fish were going to be released on May 5, 2001, the day following the pre-release exam. However, this date was postponed 5 days due to the prevalence of *Trichophrya*, because presence of this organism in chinook as well as treatment methods (i.e. formalin) may interfere with the chinooks’ ability to adapt to saltwater. Both ponds were treated with formalin on May 4, 2001. Over the next three days, the control pond had approximately 900 mortalities verses 34 in the Natures pond; increased stress from the formalin treatment likely caused fish weakened by BKD to die.

<u>Health Assessment</u>

For each health assessment, conditions of features measured were compared between the treatment and control pond (Tables 1 and 2). Two of sixty fish examined from the control pond showed signs of gross clinical BKD. Overall, health conditions were similar between the two ponds. In March and May comparisons, the condition factor was not different between the two ponds, with ktl values from 0.81 - 0.83. An overall health factor, HAI (Adams et al. 1993) was also not different between the control and Natures ponds ($p<0.05$); in March, HAI values were 14 and 19, respectively. In May, HAI values for the control and Natures pond were 20 and 16, respectively (a high HAI value would indicate less healthy fish). Out of 60 fish examined from each pond, two incidences of BKD were found within the control group; none of the fish from the Natures group had BKD.

Table 1. Fish health assessment comparison between chinook in control vs. natures pond (March, 2001). (*)= significant differences, $p<0.05$

Feature Measured	Control	Natures
Total length (L, mm)	69	70
Weight (W, g)	2.7	2.9
Condition factor (105W/L3)	.81	.82
Eyes (% Normal)	100	100
Gills (% Normal)	100	100
Pseudobranchs (% Normal)	96.67	100
Thymus (% Normal)	98.33	100

Mesenteric fat index	.87	.97
Spleen (% normal)	90.0	85.0
Hind gut (% normal)	98.28	86.67*
Hind gut index	0.02	0.13*
Kidney (% normal)	100	100
Liver (% normal)	100	100
Bile color index	.27	.15
Fin index	0.00	.02
Opercle index	.02	0
Hematocrit	48.5	47.0
HAI index ave.	14	19

Table 2. Fish health assessment comparison between chinook in control vs. natures pond (May, 2001). (*)= significant differences, p<0.05

Feature Measured	**Control**	**Natures**
Total length (L, mm)	92	92
Weight (W, g)	6.46	6.42
Condition factor (105W/L3)	.831047	.818144
Eyes (% Normal)	100	100
Gills (% Normal)	96.67	100
Pseudobranchs (% Normal)	98.33	98.33
Thymus (% Normal)	100	100
Mesenteric fat index	1.13	1.05
Spleen (% normal)	95	95
Hind gut (% normal)	100	100
Hind gut index	0	0
Kidney (% normal)	96.67	100
Liver (% normal)	96.67	98.33
Bile color index	.039	.061
Fin index	0	0
Opercle index	.017	.017
Hematocrit	44.6	46.4*
HAI index ave.	20	16

Coloration:

Due to high variation of color values among sampling dates (attributable to differences of slide film and ambient lighting differences), means relating hue, saturation, and intensity were comparable within, but not among, sampling dates. During the entire study, March-May, hue values of the control group were significantly higher ($p<0.01$) than for the Natures pond, and differences between hue values ranged from 0.67 - 1.9. Higher hue values in the control versus fish reared in the Natures pond indicate that color as observed through caudal fins of the control group were more blue than the Natures fish. In two out of three sample periods, these coloration differences are perceptible with the human eye (Figure 6, 3/8/2001 and 4/30/2001). It is possible that the color differences are due to disparity in transparency of the caudal fin; the control group fish fins may have less pigment and thus be more transparent than the treatment fish. Therefore, fins of fish in the control group may appear bluer than those of the Natures group. Further investigation will be necessary to support this hypothesis.

The Natures group had higher saturation values for March and early April samples ($p<0.02$). However, when the fish were sampled one week before release, there was no difference between saturation values ($p=0.876$). Saturation is a measure of the closeness of a color to gray; a value of 0 indicates grayness. For the first two samples, values of saturation for the control group were significantly closest to gray, but both groups were similar in grayness for the last sample.

For April 2 and 30 samples, intensity values in the Natures group were 11.3 and 16.5 higher ($p=0.00$) than the control group. For samples taken in March, differences in intensity approached significance ($p=0.063$).

References

Adams, S.M., A. Brown, and R. Goede. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. Transactions of the American Fisheries Society 122:63-73.

Goede, Ronald W. 1993. Fish health condition/procedures. Utah Division of Wildlife Resources Fisheries Experiment Station. Part 1.

B. If significant problems developed which resulted in less than satisfactory or negative results, they should be discussed.

Fish within the control pond developed BKD during final rearing. Based on the prevalence of BKD, the fish pathologist concluded that smolt to adult survival may have been affected by this outbreak. It is unknown whether the BKD outbreak in the control pond is attributable to differences in rearing conditions or as a result of vertical transmission.

C. Description of need, if any, for additional work.

It would be beneficial to begin both the Goede health assessment and photo sampling before transferring the fish from the raceways to the rearing ponds. At least two additional years of experimenting is required to evaluate the effects of the treatments on the smolt-to-adult survival.

VII. Evaluation

A. Describe the extent to which the project goals and objectives were attained. This description should address the following:

1. Were the goals and objectives attained? How? If not, why?

Objectives one through three were attained. Through observation, we determined which structures worked best, those which were used by the fish and were easily cleaned, for use in a hatchery rearing pond. Through measurement of chinook fork lengths, we tracked the growth of the control and Natures fish. Digital photography was used to evaluate differences in coloration between the two groups of fish. Using routine fish health inspections plus conducting fish health assessments using the Goede index, we compared the health of fish between the control and treatment groups. It will not be known if the final objective was attained until 2008, when most of the adult chinook will have returned.

2. Were modifications made to the goals and objectives? If so, explain.

An additional objective to compare the coloration between the control group and Natures group was added.

B. Dissemination of project results.

The results of this experiment will be disseminated in a peer reviewed journal at the completion of the project.