FINAL REPORT:

COMPARING THE SUCCESS OF THREE FISH CULTURAL STRATEGIES IMPLEMENTED TO RECOVER SNOW CREEK COHO SALMON

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ABSTRACT

Three coho salmon recovery strategies are being simultaneously evaluated in Snow Creek, a Strait of Juan de Fuca stream located in Washington State. To create the treatments, adult coho returning to the stream are captured at a permanent weir and artificially spawned. Eggs from each female are allocated into every recovery strategy. In one treatment, eyed eggs are placed in three Remote Site Incubators (RSIs) placed in Snow Creek and its major tributary Andrews Creek. In the other two treatments, fry are reared at a nearby hatchery for either seven or ten months before being released into Crocker Lake, a twenty-six hectare body of water located in the Snow Creek watershed. The program began in 1998 and smolts produced from the project have emigrated from the stream in 2000 and again in 2001. All the reared fish are tagged; those held for seven months have coded-wire tags placed in their snouts while those cultured for ten months receive tags in their adipose fins. In addition, every fish has a thermal code induced into its otoliths while it is incubating at the hatchery. These tags and marks made it possible to identify the treatment origin of each fish throughout its life cycle. Altogether, 3,828 smolts left the stream in 2000 and 7,483 emigrated in 2001. However, this last number will increase slightly as a final count of smolts leaving Snow Creek has not yet been completed. Data collected on smolts in 2000 showed that fish placed into Crocker Lake after ten-months of rearing produced the most 1+ smolts, these fish also tended to remain in the watershed for the longest period of time. Size differences were also found. At the beginning of the out-migration period, smolts originating from RSIs were larger than those produced from the other two treatments. This trend was reversed during the last half of the emigration period when fish reared for seven months were larger than individuals originating from the RSIs. Preliminary analyses of data collected on smolts captured in 2001 disclosed that many were 2+ smolts, and that most of these had originated from the fish had been reared for seven months and placed into Crocker Lake in October of 1999. The effects of each recovery strategy on smolt-to-adult survival rates, migration timing, size at maturation and other adult traits will be examined in the future.

EXECUTIVE SUMMARY

In the mid-nineteen seventies, as many as 1,400 adult coho and thousands of coho smolts were observed in Snow Creek, a Strait of Juan de Fuca stream. In the late nineteen eighties, however, drastic reductions in adult and smolt abundance occurred and it appeared that this population was in danger of extirpation. Three factors, over harvest, logging and agricultural impacts in Snow Creek, and the presence of Northern pike and other spiny rayed fishes in the watershed were apparently responsible for their decline. Recently implemented treaties, new fishery regulations, the advent of selective fisheries, habitat improvements in the basin, plus the eradication of non-indigenous fishes in the watershed, have ameliorated these conditions. Consequently, beginning in the fall of 1998, WDFW and local volunteer groups began an effort to recover this population. The program has two major objectives, first to prevent Snow Creek coho from becoming extinct, and second to simultaneously evaluate the costs and benefits of different recovery strategies.

Adult coho returning to the stream in 1998, 99, and 2000 were captured at a permanent weir located near the mouth of the stream. During each year, the fish were artificially spawned and their eggs were incubated at WDFW's Hurd Creek Hatchery. At the hatchery, eggs from every female were split into three portions, and each group received a unique thermal otolith mark for later identification. Eggs from two of the groups were placed into Remote Site Incubators (RSIs) that were established in Snow Creek and its main tributary, Andrews Creek. The remaining eggs were left in the hatchery and fish produced from them were cultured for either seven or ten months before being released into Crocker Lake, a twenty-six hectare body of water located in the Snow Creek Basin. The fish reared for seven mouths had coded-wire tags placed in their snouts while those held for ten months received tags in their adipose fins.

In the spring of 2000, three thousand eight hundred and twenty eight smolts were captured at the Snow Creek weir. The treatment origin of each smolt was determined by passing every fish through a CWT detector, those that possessed tags were then re-inspected to determine tag location. Scale and otolith samples were collected to confirm that individuals without tags were produced from the RSIs. In addition, size measurements were made on smolts representing each treatment throughout the migration period.

Analyses performed on these data showed that fish released into Crocker Lake in February had the highest survival rate, followed by those placed into the lake in October. The lengths of the smolts produced by each treatment were bi-modally distributed. The majority of the fish had fork lengths that ranged from 100 to 150 mm. However, each treatment also produced a smaller portion of fish that were 180 mm or larger. Modal size was affected by treatment. Fish reared for ten months had a greater modal size than those held for seven months which were larger than those originating from RSIs. Although RSI fish had the smallest modal size, this treatment produced the greatest percentage (8%) of fish falling into the second size mode. Some of these fish exhibited a remarkable

amount of growth exceeding 300mm in length at smoltification. Distinct differences in size also occurred during the course of the out-migration period. Fish originating from RSIs were larger than reared fish during the first twenty-five percent of the run, in the next quartile smolts from each treatment had equivalent body lengths, while in the last half of the run smolts produced from the October release were larger than individuals from the other two treatments who had similar body sizes. Out-migration timing was also affected by treatment origin. The majority of the smolts leaving Snow Creek in the early part of the run were produced by the RSIs while the fish originating from the February releases remained in the stream for the longest period of time before exiting.

Electro-fishing surveys of Crocker Lake in August and again in September 2000 revealed that many one-year old coho from all project treatments were still residing in the lake. This past spring and early summer (Late March-June 2001) we captured and interrogated over seven thousand four hundred coho smolts leaving Snow Creek. Scale analyses taken from samples of these fish indicated that approximately 25% of them were two-years old. The smolt run still is taking place and data from these fish will be used to continue the survival, timing and size evaluations of the smolts produced from the 1998 brood year and begin those assessments for coho originating from the 1999 brood year.

In the fall of 2000, eleven two-year-old coho produced from the project returned to Snow Creek. Three originated from RSIs, one came from the October Release and seven originated from fish released into Crocker Lake in February. One of these fish, a female originating from the Andrews Creek RSI had apparently left Snow Creek as a zero in 1999. It returned in 2000, as a 63 cm long fish. Depending upon marine conditions, as many as 200 adult coho originating from the project will return to Snow Creek this coming fall. The treatment origin of each of these fish will be determined, and comparisons in marine survival rates, entrance timing, body size, and other traits will be made to further refine our evaluations of the effects of each recovery strategy being used to restore Snow Creek coho. In addition, when adults become numerous enough, some will spawn naturally in Snow Creek to produce a fourth, recovery option. The performance of these fish will be compared against the other treatments when smolts and adults produced by natural reproduction become available.

PURPOSE

Description Of The Problem

There is a current need to identify how to recover extremely depressed or extirpated populations of coho salmon in Puget Sound, along the Straits of Juan de Fuca, coastal Washington (e.g. Willapa Bay) and in the Lower Columbia River. This study is designed to simultaneously evaluate the biological costs and benefits of three recovery strategies, incubation and liberation from Remote Site Incubators, and hatchery rearing for seven or ten months and subsequent release into natal stream areas as pre-smolts. When adult abundance allows, unfed fry originating from the hatchery will be released into portions of the watershed and adult coho will also be allowed to spawn naturally in the basin to determine the success of fry plants and natural production.

Salmon hatcheries are designed to provide environments that promote high survival rates during early life history stages. Under natural conditions, mortality often exceeds 90% from fertilization through early post-emergent life. By protecting embryos and juveniles from random mortality events, hatcheries can serve as critically important refugias in salmon recovery programs. However, their use may also induce inadvertent domestication effects. Thus, in order for recovery efforts to occur with minimal biological costs and maximal survival advantages it is imperative that we understand all the consequences of our cultural strategies and then make management decisions based on this information. The results of this study will help us make informed choices about how to conduct coho recovery programs throughout western Washington.

Objectives Of The Project

The specific research and objectives of this project are as follows:

1) To determine the fry-to-smolt survival rates of coho juveniles originating from RSIs, from plants of pre-smolts into Crocker Lake after either seven or ten months of artificial rearing, and when adult abundance allows, from unfed fry plants and natural production.
2) To trap all the coho smolts emigrating from Snow Creek and identify their treatment origin.
3) To document the arrival time and size (length) of smolts originating from each treatment just before the fish enter seawater.
4) To measure and compare the smolt-to-adult survival rates of fish originating from each treatment group.
5) To measure and compare phenotypic and behavioral attributes of adult coho produced from each treatment strategy.
6) To analyze the recovery data collected on smolts and adults to ascertain the effects of environmental variation on the survival and performance representing each treatment strategy.

APPROACH

Description of The Work That Was Performed

Collection of Adult Coho at the Snow Creek Weir Since 1998, we have attempted to capture every adult coho salmon returning to Snow Creek at a permanent weir located 1.2 kilometers above the mouth of the stream. Each year, a few adult coho are observed spawning below the weir, but almost all of the fish entering the stream are caught and retained at the weir. Upon capture, the fish are sexed, inspected for maturity, individually placed into 20 cm in diameter by 90 cm long holding tubes, and held until they reach maturity and can be spawned. Data on the arrival time of each fish is recorded. Beginning in 2000 each returning adult was inspected for CWTs and also had scales and otoliths removed so that it would be possible for us to determine if they had originated from any of our recovery treatments.

Staff from WDFW's Hurd Creek Hatchery routinely inspect each captured fish and determine when it should be spawned. Prior to gamete extraction, each fish is weighed and measured, and as mentioned above, scales and otoliths were collected beginning in the fall of 2000. In addition, the general condition of every fish is recorded which can range from excellent to poor depending upon fin wear, scale loss, presence of fungal infestations and general appearance. DNA samples and ovarian fluid, milt, spleen and kidney tissues are also collected. The DNA material is being archived while WDFW's Fish Health Laboratory in Olympia screens the pathogen samples.

At spawning each adult fish is given a unique sequential number to enable us to track the viability of their gametes while they remain in the hatchery. For example, the first female spawned is designated as F-1, the next female as F-2 and so on. Thus, if a total of 16 females were spawned over a four-week period, the last female would be labeled as F-16. A similar numbering system is used to keep track of each male. All spawning takes place at the Snow Creek weir, but egg fertilization occurs at the Hurd Creek Hatchery. This approach was taken to limit any pathogen transfer between Snow Creek and Hurd Creek Hatchery. To facilitate gamete transfer, eggs and ovarian fluid obtained from each female are placed into plastic zip lock bags. The bags are then filled with oxygen and stored in coolers equipped with crushed ice covered with a layer of moist burlap or other insulating material. Milt from each male is processed in a similar fashion.

Fertilization and Incubation Procedures Once the gametes arrive at the hatchery, the egg mass weight, mean green egg weight, and fecundity of each female is determined. In addition, ten eggs are randomly removed from each female, placed into water for twenty-four hours and then weighed to the nearest mg on an electronic balance to determine a mean wet egg weight for each fish. Factorial crosses; 3 x 3, 2 x 2 or other similar designs are used to mate the fish. To produce a 3 x 3 cross for example, the eggs from each female being used are subdivided by weight into three equal groups. Each group is then placed into a clean and dry plastic pail. In this instance a total of nine such pails are produced and they are arrayed in 3 x 3 matrix, with the eggs from each female placed into

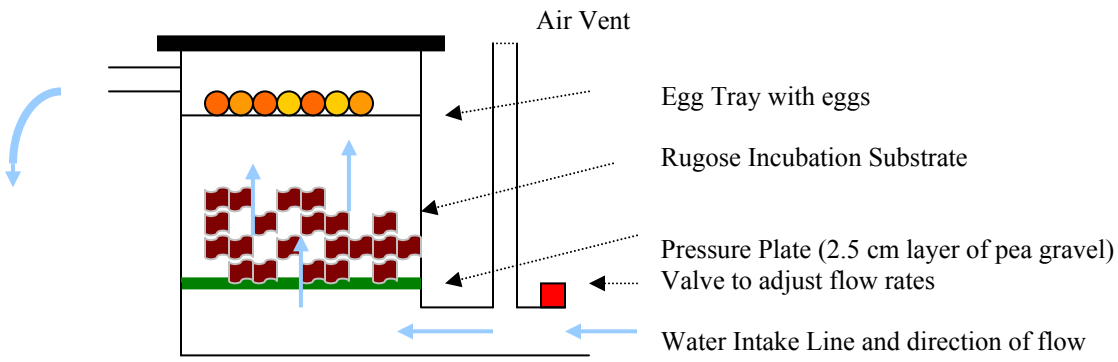
a column. Milt from three different males is used to fertilize the eggs lots in each row, in this fashion, each male fertilizes one third of each female's eggs. After milt has been added the gametes are activated by adding water and the gametes are gently stirred. Two minutes after activation all the eggs from a single female are recombined and poured into an iso-bucket, which is held in an Iodine-based disinfectant for one hour before receiving a running supply of hatchery water. At the eyed-stage of development, the eggs from each female are shocked; mortalities are removed and counted by hand. Gravimetric estimates of the number of eyed eggs produced by each female are also made at this time.

Creation and Thermal Marking of the Treatment Populations During the first three years of this project, three recovery treatments, incubation and release from RSIs, seven- and ten-month hatchery rearing and liberation into Crocker Lake in October (7-month treatment) and February (10-month treatment) have been used. Eggs from each female have been allocated into every strategy in a proportionate fashion. In brood year 1999, for instance, 56, 045 eyed eggs were obtained. Thirty-seven thousand three hundred and sixty three of these eggs or 66% of them were placed into the RSI strategy while 16% were used in each of the rearing programs. Consequently, during this year, two-thirds of each female's eggs were allocated into the RSI strategy and one-sixth was placed into each rearing and release option. Similar, proportionate allocations of eggs occurred in 1998 and again in 2000.

Once eyed eggs had been allocated into their respective treatments their otoliths are thermally marked by purposively manipulating incubation temperatures (Volk et al. 1999). Two thermal codes are used each year for the RSI fish, one for those placed into RSIs located in Snow Creek and another for those incubating in the RSI situated on Andrews Creek. The fish destined for the rearing treatments at the hatchery receive another code. So far, all the codes used are unique, making it possible to not only identify a fish's rearing treatment but also its brood year.

Thermal codes can be induced into otoliths both before and after hatching. Conveniently a diagnostic check occurs on salmonid otoliths at the time of hatching and it is therefore possible to produce recognizable pre- and post-hatch codes. Fish produced from the RSIs only have pre-hatch codes since they are placed into their RSIs at the eyed-egg stage. Conversely, fish used in the rearing treatments have both pre- and post-hatch codes.

Three, 208 liter (55 gallon) RSIs were established in the Snow Creek Basin in 1998. Two are located on Snow Creek and one has been placed on Andrews Creek approximately 1.9 kilometers above Crocker Lake. Each RSI has been filled with bio-rings and plastic saddles and is supplied with 35 to 50 liters of water per min. A diagram showing the internal structure and water pathway in RSIs is illustrated in Fig. 1. Part B of this figure shows coho eggs being added to a Snow Creek RSI. Standard Heath Trays are used to incubate the eggs retained at Hurd Creek and used to produce the seven-month and ten-month rearing groups.



A

B

Fig. 1. Part (A) is a schematic view of a typical RSI showing that water enters the bottom of the structure and up-wells past a pressure plate, into the incubation chamber and continues through the egg trays and out an exit opening. When fry emerge they swim out through the exit pipe. Part (B) is a photograph showing coho eggs recently placed into a 55-gallon (208 L) RSI located in Snow Creek. Because eggs are placed into Snow Creek RSI multiple times, they are poured directly over the substrate and not placed on trays. During incubation an opaque lid is placed over the device to protect the eggs and developing alevins from light.

Rearing Environments For Each Treatment Fish placed into RSIs volitionally exit and enter either Snow or Andrews Creek where they begin their freshwater rearing phase. Coho retained at the hatchery are reared in 1.5 m wide by 12.2 m long by 1.1 m deep fiberglass raceways that can be supplied with up to 379 liters (100 gallons) of water per minute. The fish are fed a standard hatchery diet and routine monitoring of growth and mortality is carried out over the rearing period. Prior to being released, the fish in each rearing strategy receive CWTs. Those released into Crocker Lake in October have blank coded wire tags placed in their snouts while those liberated in February have blank wire inserted into their adipose fins. At the completion of their rearing period, the fish are starved for at least 24 hrs before being gently crowded, seined from their raceways, placed into a planting truck, and hauled to Crocker Lake.

Capturing Downstream Migrating Smolts The permanent weir located at river kilometer 1.2 is used to capture all the coho smolts emigrating from Snow Creek. In mid- to late-March, screen panels are inserted into the weir and downstream migrants are diverted through a V-trap and live box holding area. When necessary, the upstream pool created by the weir is seined to force smolts into the live box. Each coho smolt is counted by hand and passed through a Coded-Wire Tag "R-Series Detector". Those individuals with tags are interrogated further with hand-held CWT wands to determine the body location of their tags. The number of fish with and without tags is recorded daily. A small sample of smolts without tags (~100) have been proportionately removed and sacrificed each year. Their otoliths are extracted and decoded to test the assumption that fish without CWTs had originated from RSIs and were not reared fish that had lost their tags or naturally produced smolts. Scales were collected from 90 smolts in 2000 and from 407 fish in 2001. These samples were collected to determine the age structure of the out-migrating smolts. In addition, 1,211 smolts were measured (fork length) in 2000 while 2,665 fish had fork lengths taken in 2001. These data are being used to determine if size differences exist among smolts originating from different treatments and during different parts of the smolt migration period. Moreover, preliminary examination of the scales collected in 2001 indicated that a significant number of smolts were 2+ fish. The length and age data collected in 2001 will be used to estimate how many 0, 1+ and 2+ smolts emigrated from the stream.

Statistical Procedures Used This project is designed to address a number of specific questions that examine the effects of the three alternative recovery strategies being used on Snow Creek coho. So far, we have trapped, measured, and enumerated smolts in 2000 and again in 2001. In addition, a few (11) adult coho produced from the project returned as 2+ fish this past fall. As of this writing, smolts are still emigrating from Snow Creek; consequently data analyses have not been conducted on any of the information gathered on fish leaving the basin in 2001. Data collected on smolts leaving Snow Creek in 2000 were used to address the following three questions: 1) Is there a difference in the fry-to-smolt survival of fish that were placed into the three different recovery strategies? 2) Do smolts produced from each recovery strategy have similar body lengths and is there an interaction effect between recovery treatment and when a fish chooses to emigrate, i.e. date of emigration? And, 3) Did fish from each recovery treatment emigrate from Snow Creek at the same time? Chi Square tests were used to examine the first question. A two-way ANOVA with fixed treatments (Recovery Treatment and Time of Emigration) examined the relationships between treatment origin and body size. Finally, a series of Kolmogorov-Smirnov Two-Sample tests were used to examine whether fish from the treatments exhibited different emigration rates. Since three of these tests were performed on the same data set, the Bon Ferroni correction procedure was used to adjust the alpha level. Once, adult coho produced from the project return to Snow Creek data collected on the fish will be used to determine whether treatment origin affects their: 1) smolt-to-adult survival rates, 2) entrance timing into Snow Creek, 3) size at maturation, 4) proclivity to produce precocious males (jacks), 5) fecundity and egg sizes, and 6) reproductive effort values in females. None of these tests have been performed yet because only 2+ adults have had an opportunity to return to the stream. In 2001 we expect 100 or more 3+ adults to return to the steam making the above analyses possible.

Project Management

The Washington Department of Fish and Wildlife (WDFW), North Olympic Salmon Coalition (NOSC), and Wild Olympic Salmon (WOS) are conducting this project. WDFW personnel are responsible for all aspects of the project. However, volunteers from NOSC and WOS have, and continue to play critical roles. They check each RSI on a daily basis during the incubation season to ensure that the devices are functioning properly. In addition, they assist WDFW staff during the smolt out-migration period by helping to interrogate captured smolts with CWT detector equipment, and also assist in collecting length and scale data.

Personnel from WDFW's Region Six, the Hatchery, and Science Divisions work on the project. Region Six staff located at Snow Creek are responsible for capturing all the adult coho used in the project. They help spawn the fish and collect biological data on the adults and their subsequent offspring. Moreover, regional staff established the RSIs located in Snow and Andrews Creeks and make sure that the RSIs are operating properly. Region Six staff also direct the smolt trapping and enumeration operation that occurs from mid-March through June and assist Science Division staff conduct electro-fishing surveys in Crocker Lake in August and September. Personnel located at the Hurd Creek Hatchery, determine when each fish should be spawned, incubate and thermally mark fish in each treatment and also culture and release the coho used in the seven- and ten-month rearing groups. In addition, hatchery division staff apply CWTs to the reared fish. Science Division and Region Six staff designed the study, age all the scale samples, create thermal otolith codes, decode all otoliths collected, analyze data originating from the study, and are responsible for producing project reports.

FINDINGS

Accomplishments and Findings

Collection of Broodstock During the fall of 1998, 1999, and 2000 adult coho salmon returning Snow Creek were captured and spawned at the Snow Creek weir. Basic biological information, weight, length, age, fecundity, egg size, reproductive effort, DNA, and pathology samples were collected on each spawned adult. In Table 1 the number of Snow Creek coho used as brood stock and the survival of their eggs to the eyed stage in 1998, 1999, and 2000 are presented. In Table 2, eyed egg to fry survival rates are shown for the RSI groups and survival to release into Crocker Lake for the seven- and ten-month reared groups are presented. In addition, Table 2 also displays the number of fish allotted into each recovery strategy for three brood years.

Table 1. The number of adults used as brood stock in 1998, 1999, and the survival of their eggs to the eyed stage of development.

Brood Year	Type of Adult Coho Used As Brood Stock			No. Of Green Eggs Taken	Green Egg to Eyed Egg Survival
	♀	♂	Jacks		
1998	19	19	2	34,989	89.5%
1999	25	36	9	60,580	92.5%
2000	19	11	14	48,556	91.1%

Table 2. The number of eggs allotted into each release strategy from the 1998, 1999, and 2000 brood years and their in-culture survival rates.

Brood Year	Release Strategy	No. Of Eyed Eggs Allotted	Eyed Egg To Fry Survival	Fry To Release Survival	Mean Size At Release
1998	RSI Andrews Creek	7,764	99.1%	99.1%	Unfed Fry
	RSI Upper Snow	3,900	98.7%	98.7%	Unfed Fry
	RSI Lower Snow	3,899	97.9%	97.9%	Unfed Fry
	Reared 7 Months Released Into Crocker Lake	7,467	99.2%	99.2%	12.26 g
	Reared 10 Months Released Into Crocker Lake	7,467	99.2%	99.2%	15.64 g
1999	RSI Andrews Creek	18,682	99.7%	99.7%	Unfed Fry
	RSI Upper Snow	9,340	99.7%	99.7%	Unfed Fry
	RSI Lower Snow	9,341	85.2%	85.2%	Unfed Fry
	Reared 7 Months Released Into Crocker Lake	9,341	98.7%	96.4%	11.63 g
	Reared 10 Months Released Into Crocker Lake	9,341	98.7%	93.7%	23.14 g
2000	RSI Andrews Creek	12,940	97.8%	97.8%	Unfed Fry
	RSIs Snow Creek	12,940	97.8%	97.8%	Unfed Fry
	Reared 7 Months Released Into Crocker Lake	9,164	96.9%	In Progress	In Progress
	Reared 10 Months Released Into Crocker Lake	9,165	96.9%	In Progress	In Progress

As Tables 1 and 2 illustrate egg viability was generally high. In those few instances were fertilization rates were low, the females had often died prior to being spawned and their egg quality had been compromised. Moreover, mortalities from the eyed stage to emergence or ponding were also very low expect for one instance in 1999 when fourteen percent of the eyed eggs placed into the RSI located in lower Snow Creek perished. This occurred because the alevins produced from these eggs migrated below the gravel pressure plate of their RSI and became entombed. Other than this one incidence, egg-to-fry survival rates in the RSIs have ranged from 98 and 99%. Mortalities during the rearing period at Hurd Creek have been exceptionally low, often less than 3% over an entire rearing period.

Survival, size, and out-migration timing of smolts produced from each release strategy

Smolts produced from the 1998 and 1999 brood years have emigrated from Snow Creek and tallies of their abundance and treatment origin were accomplished. During the spring of 2000, three thousand and twenty-eight coho smolts were captured and interrogated at the Snow Creek Weir. All of these fish were one-year old smolts. In 2001, seven thousand four hundred and eighty-three smolts were captured as of 21 June 2001. Since then, additional individuals have emigrated from the stream and even now in early July 2001, smolts are still leaving the stream. These data have not been placed in Tables 3 and 4; therefore the numbers presented in the tables will change once the smolt migration has been completed. However, the abundance of these fish is relatively small and they should not affect the overall results discussed below.

Scale samples taken from fish in 2001 have indicated that many of them are two-year smolts, indicating that they originated from the 1998 brood year. In Table 3 the numbers of smolts originating from each treatment that have emigrated from Snow Creek in 2000 and 2001 are presented.

Table 3. The number of coho smolts originating from three different recovery strategies captured at the Snow Creek weir during the spring of 2000 and 2001.

Collection Year	Rearing Treatment		
	Seven-Month Rearing Period & October Release Into Crocker Lake	Ten-Month Rearing Period & February Release Into Crocker Lake	RSI, Volitional Release into Snow & Andrews Creeks
2000	683	1944	1201
2001	1513	2118	3852

Currently we are using the aforementioned scale samples to develop relationships between fish size and age at smoltification. Separate relationships are being developed for fish originating from each treatment. Since temporal changes in fish size may occur, separate age and length relationships for every treatment are being established for the first, second, and last third of the out-migration period. During the downstream trapping period in 2001 preliminary assessments of smolt age were made by using body length data. The results of this early assessment are presented in Table 4.

Table 4. The estimated number of 1+ and 2+ smolts produced by each recovery strategy tried in Snow Creek for the 1998 and 1999 brood years. Two-year old smolts from the 1999 brood year will emigrate from Snow Creek during the spring of 2002.

Brood Year	Rearing Treatment					
	Seven-Month Rearing Period & October Release Into Crocker Lake		Ten-Month Rearing Period & February Release Into Crocker Lake		RSI, Volitional Release into Snow & Andrews Creeks	
	1+ Smolts	2+ Smolts	1+ Smolts	2+ Smolts	1+ Smolts	2+ Smolts
1998	683	1084	1944	326	1201	659
1999	429	-	1792	-	3193	-

So far, the smolt trapping data have been used to make two assessments. First Chi Square tests were performed on information collected in 2000 to see if the capacity to produce 1+ smolts was affected by the recovery treatment the fish experienced. When this test compared smolt production from all three strategies, a significant Chi Square (X^2) value of 1,667 was obtained ($1,667 >> X^2 0.05, 2 = 5.991$). The fish reared for ten-months accounted for most of this Chi Square value. This group was then removed, and another Chi Square test using Yates correction factor was performed using methods described by Zar (1974). Once again a significant X^2 value was obtained ($5.8233 > X^2 0.05, 1 = 3.841$). In aggregate the tests disclosed that the ten-month rearing treatment produced the most 1+ smolts, followed by the seven-month rearing treatment and then the RSI strategy. All treatments however achieved remarkably high survival rates. For example, for every 1000 eyed eggs invested in the ten-month rearing treatment, 276 one-year old smolts were produced, similarly the seven-month rearing strategy provided 87 smolts and the RSIs created 77 smolts per one thousand eyed eggs. Naturally reproducing coho average about 22 smolts per thousand eggs. These numbers will of course go up once a refined estimate of the number of two-year smolts can be made.

The data presented in Tables 3 and 4 indicate that the number of 2+ smolts produced appears to be affected by treatment origin. For example, about 61% of all the smolts produced from the seven-month rearing treatment were two-years old when they left Snow Creek. Conversely, only 14% of all the smolts produced from the ten-month treatment emigrated at two-years of age while 35% of the RSI fish smolted at age two. Chi Square Tests confirmed that there were significant treatment effects ($625.2 >> X^2 0.05, 2 = 5.991$). In this case, the treatment contributing the highest value to the Chi Square sum was the seven-month treatment. This treatment was removed and a subsequent test was performed using Yates Correction factor to examine whether RSIs and the ten-month treatment differed in their proclivity to produce two-year old smolts. A Chi Square value of 189.39 ($>> X^2 0.05, 1 = 3.841$) was obtained indicating that fish originating from RSIs had a greater tendency to produce 2+ smolts than individuals released into Crocker Lake in February. Generally, two-year old coho smolts are not commonly seen in Washington State unless they have an opportunity to rear in lakes. We hypothesize that the differences reported here are linked to lake residency. Fish released into Crocker Lake in October apparently find abundant food, which must interact with their smoltification

cycle, causing them to delay their out-migration. The RSIs are situated so that about fifty percent of the fish produced from this treatment can enter Crocker Lake by making a simple downstream migration. It is likely that many do and the good growth they achieve in the lake has also extended their freshwater rearing period. The fish released into Crocker Lake in February, on the other hand, probably spend some of their time simply recovering from transportation stress, and may not experience a prolonged period of rapid growth. Plainly, the causes responsible for inducing the production of 2+ smolts are not known. Whether similar proportions of 2+ fish will be produced by each treatment in succeeding brood years remains to be seen. Perhaps as more and more coho occupy Crocker Lake the propensity to produce such migrants will decrease.

Length data collected on smolts (1+) leaving Snow Creek in 2000 were examined to see if treatment origin affected body size. In this instance, a two-way ANOVA was used to simultaneously test: 1) whether treatment origin affected smolt size at emigration, 2) if when a fish emigrated affected its size, and 3) whether there was an interaction between release treatment and time on smolt size. The results of this ANOVA are summarized in Table 5.

Table 5. The results of a two-way ANOVA that examined the effects of treatment origin and time of emigration on the size of 1+ smolts produced from Snow Creek in 2000.

Analysis Of Variance Summary

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Sums of Squares
Total	348839.4	455	
Cells	54669.9	11	
Release Treatment	4120.8	2	2060.4
Migration Period First, Second, Third, and Fourth Quartile Of Emigration Period	12029.8	3	4009.9
Treatment x Quartile Interaction	38519.3	6	6419.9
Error	294169.5	444	662.5

Hypothesis Tested	F value	Decision
Release treatment has no affect on smolt size	3.11	Fail to reject H_o as F.05, 2, 444 = 3.72
Time (first, second, third, and fourth quartile) at emigration has no affect on smolt size	6.05	Reject H_o as F.05, 3, 444 = 3.14
There is no interaction between release treatment and time on smolt size	9.69	Reject H_o as F.05, 6, 444 = 2.84

The ANOVA showed that there was no overall difference in mean size caused by treatment origin ($F = 3.11 < F.05, 2, 444 = 3.72$). However, there were significant time and time and treatment interactions that affected smolt size. These can be seen in Table 6 where mean lengths by time period for smolts originating from each treatment are displayed.

Table 6. The mean size of 1+ coho smolts originating from three different recovery treatments that emigrated from Snow Creek in 2000 during the first, second, third, and fourth quartiles of the out-migration period.

Time Period (Quartile)	Rearing Treatment		
	Seven-Month Rearing Period	Ten-Month Rearing Period	RSI
First	135.2	131.7	167.1
Second	137.3	131.9	127.5
Third	150.2	142.2	128.0
Fourth	144.7	134.3	127.0.
Overall Mean	141.2	134.4	141.5

Student Newman Multiple Comparison Tests were performed on the size data and a visual representation of the results of these tests are shown in Table 7. They indicate that RSI origin smolts were larger than fish produced by both the seven- and ten-month rearing programs during the first 25% of the run. In the next quartile (26 –50%) no size differences were found while during the last two quartiles fish originating from the seven-month treatment were larger than smolts originating from the RSIs.

Table 7. Results of the Student Newman Multiple Comparison Tests used to examine size differences in coho smolts (1+) emigrating from Snow Creek in 2000. Groups of Fish with similar body sizes are underlined.

Time Period	Results of SNK Tests
First Quartile	RSI Fish > Seven- & Ten-Month Reared Fish
Second Quartile	Seven-, Ten-Month Reared Fish, RSI Fish
Third Quartile	Seven-Month & Ten-Month Reared Fish Ten-Month Reared Fish, RSI fish
Fourth Quartile	Seven-Month & Ten-Month Reared Fish Ten-Month Fish, RSI Fish

An examination of the length frequency distributions of the smolts produced from each treatment showed that their modal size increased the longer they were under artificial culture. As Fig. 2. illustrates, all the groups also exhibited a bimodal distribution in their lengths. In this case, it appears that the treatment that reared the longest in Crocker Lake (the seven-month reared group) had the greatest proportion of fish in the right hand mode, next came the RSI fish that probably entered the lake to over-winter and then the ten-month group which had the smallest number of fish in the right-hand mode. The RSI treatment, however, produced the largest smolts, e.g. approximately 8% of these fish equaled or exceeded 200 mm in length and 2.4% of them were 300 mm or longer. To reach this size after just one year of freshwater rearing is extraordinary. This phenomenal growth probably occurred because some of these fish entered Crocker Lake at the fry stage and were able to exploit its abundant food resources. Conversely, the hatchery reared fish released into Lake in October (seven-month group) had 1.2% and 0.3% (ten-month group) of their smolts larger than 200 mm and none of these fish were longer than 219 mm.

Kolmogorov-Smirnov Tests (Zar 1974) were used to determine if smolts (1+) produced by the three recovery treatments emigrated from the watershed at different rates. In this test we compared the cumulative out-migration frequency distribution obtained on RSI fish against those observed on the seven-month and ten-month reared treatments. The results of these tests indicated that coho smolts originating from RSIs left the watershed more rapidly than those produced from either of the reared fish treatments ($D = .1091 > D.0167,1816 = 0.0363$ for the ten-month group; $D = .1429 > D.0167, 683 = .0592$ for the seven-month rearing treatment). An additional Kolmogorov-Smirnov test compared the cumulative out-migration frequencies of the two reared groups, here it was determined that smolts (1+) originating from the seven-month rearing treatment exited the watershed sooner than fish produced from the ten-month rearing strategy ($D = .1316 > D.0167, 683 = .0592$). In Fig.3. the cumulative out-migration frequencies of 1+ smolts emigrating from Snow Creek in 2000 originating from the RSI and ten-month rearing treatments are compared.

In summary, significant biological differences have been observed among the smolts produced by each recovery strategy. For example, a clear difference in the proportion of fish emigrating as 2+ smolts has occurred among the treatments. Size and timing of emigration apparently have also been affected by treatment and putative residency in Crocker Lake. Whether these differences will persist from one brood year to the next remains to be ascertained, and how or if, they affect smolt-to-adult survival is presently unknown. What is becoming clear, however, is that Crocker Lake has had a large impact on the performance of these fish. It appears to be a very food-rich body of water that is allowing our treatment groups to achieve remarkably high survival rates and large sizes at smoltification. An important consequence is that the Snow Creek coho population is showing signs of recovering.

Significant Problems and Additional Work

The Andrews Creek RSI site was significantly altered by the property owner just prior to the 2001 incubation season. Unfortunately, the earthwork performed stopped the ground water supply that was used by this RSI. Consequently, the eyed eggs that were set-aside for that RSI were placed into one established on Snow Creek. As coho fry emerged, they were transported approximately 1.2 kilometers and released after sunset into Andrews Creek; a process that took fifteen minutes or less. We hope to repair this site prior to the next incubation season or find another location in the Andrews' Creek drainage.

Second, the large number of 2+ smolts produced by the project was unexpected. During this past out-migration season we collected four times the scale samples that were collected in 2000 in an effort to accurately assign ages to each smolt. We will increase this sampling effort in future out-migration seasons in order to continue to obtain an accurate assessment of the age composition of the smolts leaving Snow Creek.

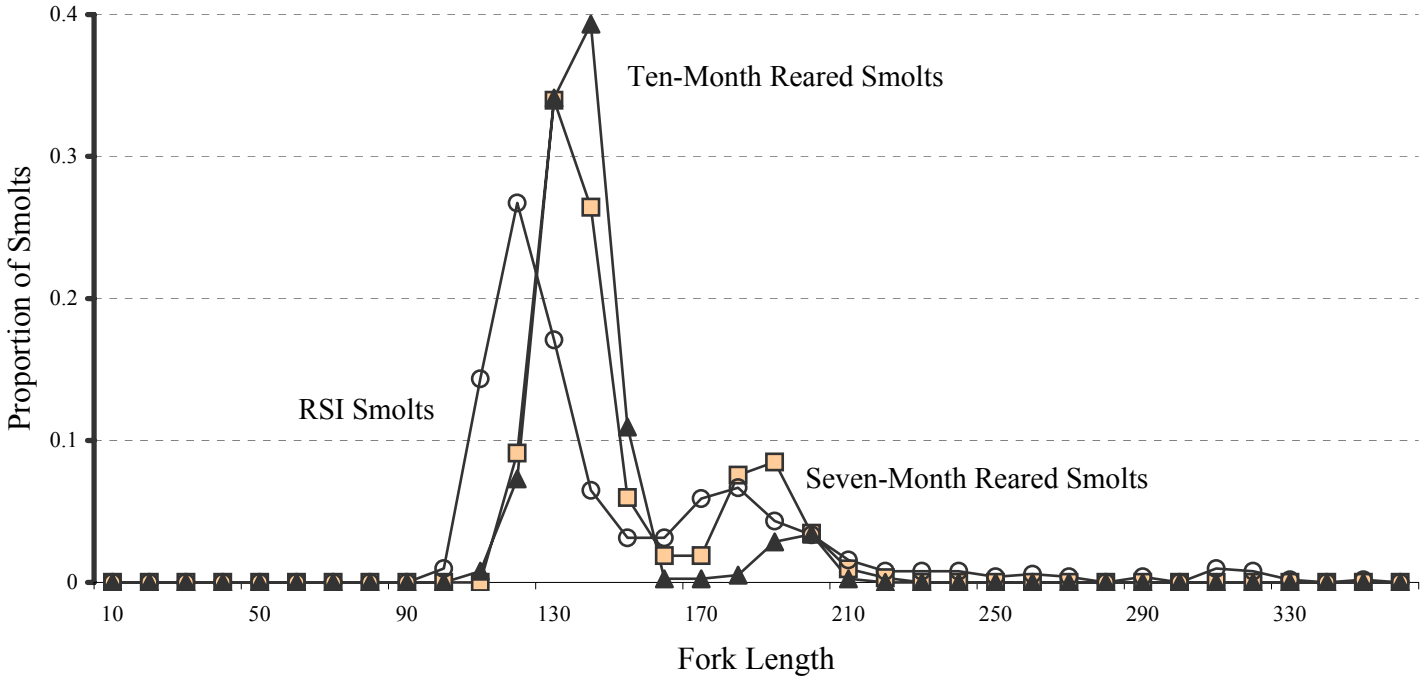


Fig 2. The length frequency distributions of 1+ coho smolts migrating from Snow Creek in 2000 that originated from three recovery strategies.

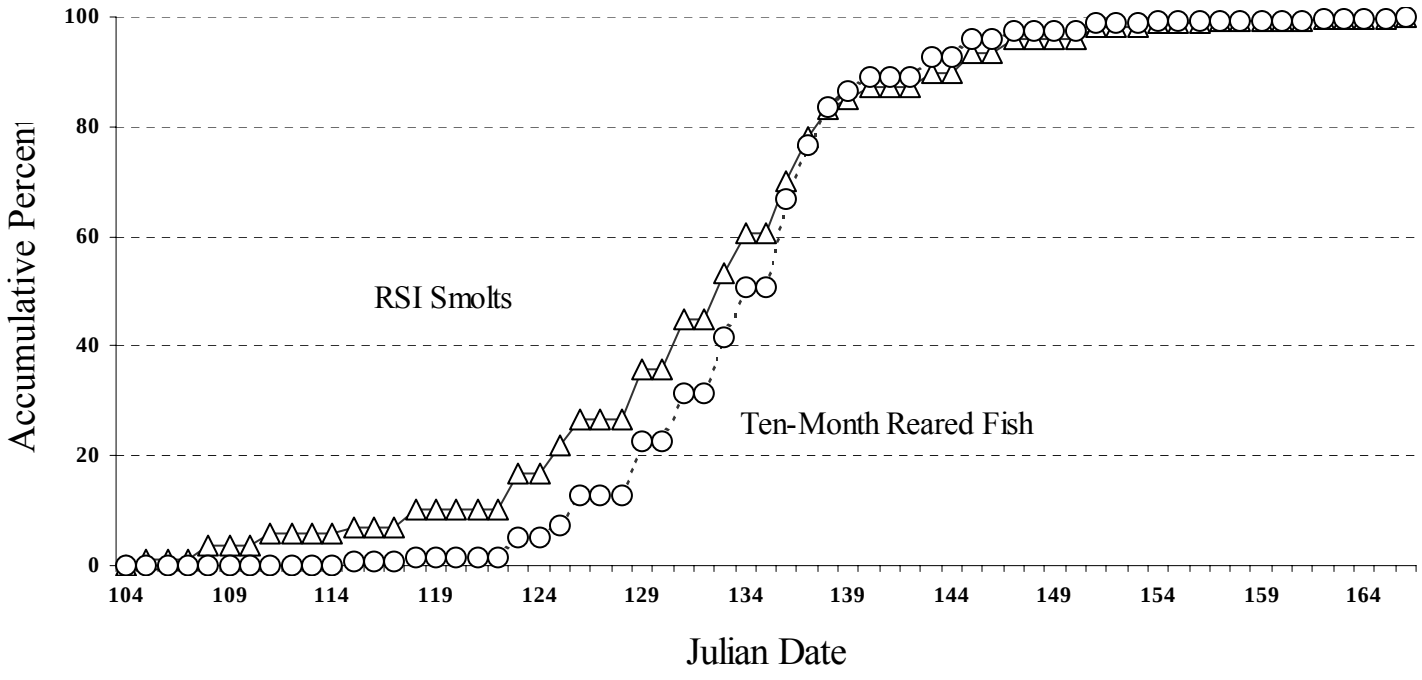


Fig. 3. The cumulative out-migration frequencies of 1+ smolts in Snow Creek during the spring of 2000 that originated from RSIs and the ten-month rearing treatment.

EVALUATION

Attainment of Project Goals and Objectives

All project goals were accomplished by using the methods described in the APPROACH portion of this report. No modifications were necessary except for having to transport RSI treatment fish from Snow Creek to Andrews Creek as described above. Efforts will be made to once again establish a fully functioning RSI on Andrews Creek so that this will not be necessary in future years.

Dissemination of Results

We plan to submit a paper describing the results of this work to a peer-reviewed publication after we obtain several years of adult returns so that the immediate consequences of each treatment tried can be followed to the adult stage. Results to date have been shared with the HSRG committee and with the local volunteer groups who are helping us conduct this work.

Literature Cited

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, N.J. 620 pp.