An Evaluation of Rearing Density in Relation to Post-Release Smolt Survival and Adult Returns of Spring Chinook Salmon at Dworshak National Fish Hatchery in Idaho

Final Report

Prepared by:

Ray N. Jones
Idaho Fishery Resource Office
U.S. Fish and Wildlife Service
Ahsahka, Idaho

and

William H. Miller
Dworshak Fisheries Complex
U.S. Fish and Wildlife Service
Ahsahka, Idaho

Prepared For:

Dan Herrig
Lower Snake River Compensation Plan
U.S. Fish and Wildlife Service
Boise, Idaho

August 1996

Table of Contents

Acknowledgments

Funding for this project was provided by the U.S. Fish and Wildlife Service through the Lower Snake River Compensation Plan Program. Project design and data analysis was performed by the Idaho Fishery Resource Office. Dworshak National Fish Hatchery was responsible for all production aspects of the project. The Dworshak Fish Health Center provided fish health and smolt development examinations. Aldo Palmisano conducted standardized seawater rearing evaluations at the Marrowstone Field Station (National Biological Survey). The following individuals all made important contributions to the project over its six year duration: Jon Streufert, Mark Maskill, and Doug Lawson provided production supervision. Ron Oatman, Ben Wright, John Vargas, and Terry Weeks provided daily care and feeding. Ralph Roseberg provided information on coded-wire tag returns. Joe Lientz, Kathy Clemens, Elizabeth Steiner and Colleen Hesson provided fish health and smolt monitoring services. Diane Praest, Amy Kishpaugh, and Kay Cole typed this and previous manuscripts. Aaron Garcia, Billy Connor, Howard Burge, Anne Rockhold, Pat Bigelow, Michelle Bouchard, and Ken Peters, as well as many of those previously mentioned, provided review and comments.

Introduction

Considerable research has been conducted to determine the effects of rearing density on the quality and performance of anadromous salmonids, both before and after smolts have been released from the hatchery. Rearing density has been shown to have an effect on growth (Banks and Fowler 1982; Fagerlund et al. 1981, 1983; Ewing et al. 1981; Martin and Wertheimer 1989; Schreck et al. 1985), mortality during hatchery rearing (Fagerlund et al. 1981, 1984, and 1987; Banks 1994), susceptibility to disease (Schreck et al. 1985), fin erosion and gill filament quality (Banks and Fowler 1982), level of stress (Fagerlund et al. 1981, 1983, 1984, and 1987), physiological development that may affect the process of smoltification (Schreck et al. 1985; Patino et al. 1986), and survival to adulthood after release (Hemmingsen et al. 1979; Fagerlund et al. 1987; Martin and Wertheimer 1989; Banks 1992 and 1994; Denton 1988; Sandercock and Stone 1982; Downey et al. 1988). However, not all of the studies are in complete agreement as to whether higher rearing densities have a negative or positive effect.

Ewing and Ewing (1995) reviewed all the rearing density research in the Pacific Northwest that reported adult yields of coho (*Oncorhynchus kisutch*) or chinook (*O. tshawytscha*) salmon to determine the effects of rearing density on survival to adult. Data from 20 brood years of coho salmon and 15 brood years of chinook salmon were examined and summarized. Their results indicated that, with coho salmon, the number of adults that returned per rearing container increased as rearing density increased for 15 of the 20 brood years examined. For chinook salmon, higher rearing densities increased the number of adults that returned per rearing container in four of the 15 brood years examined. In seven of the 20 brood years for coho salmon, higher density reduced survival to adulthood. In the 14 brood years for chinook salmon, higher density reduced percent survival. Banks (1994) concluded that the inconsistent results reported in the literature probably reflects site-specific differences in water quality, disease, rearing containers, and the species tolerance to crowding. Because of that, optimum rearing densities are probably site-specific (Banks 1990).

In an effort to improve the production efficiency of spring chinook salmon at Dworshak National Fish Hatchery (NFH), juveniles from two brood years were reared at three different densities to determine the effects of rearing density on smolt survival and adult returns. Additional data on rearing mortality, fish health, smolt migration time to various lower Snake River dams, and survival during extended seawater rearing trials is also included, although it was not part of the original study plan.

Site Description

Dworshak NFH is located at the confluence of the North Fork and the main-stem of the Clearwater River about 64 km east of Lewiston, Idaho (Figure 1). Construction of the hatchery was included in the authorization for Dworshak Dam and Reservoir (Public Law 87-847, October 23, 1962) to mitigate for losses of anadromous steelhead (*O. mykiss*) caused by the dam and reservoir.

The hatchery was designed and constructed by the U.S. Army Corps of Engineers (COE) and has been administered and operated by the U.S. Fish and Wildlife Service (USFWS) since the first phase of construction was completed in 1969. Additional construction was completed in 1982 under the Lower Snake River Compensation Plan (LSRCP) to provide rearing facilities for spring chinook salmon. A total of thirty 8-foot by 80-foot raceways were constructed. Dworshak NFH was originally scheduled to produce 1.4 million spring chinook salmon smolts, 70,000 lbs at 20 fish/lb, annually (Corps of Engineers 1981). Starting in 1986, twelve 8-foot by 75-foot raceways were converted from rainbow trout rearing to chinook salmon rearing. The total rearing capacity at Dworshak NFH was increased to 1.7 million smolts or 90,000 lbs at 20 fish/lb. This regime called for rearing chinook at an average density of about 45,000 fish/raceway. In 1993, two of these 8-foot by 75-foot raceways were converted to an adult holding pond, lowering the production capacity.

Methods and Materials

Fish Culture

Brood Year 1989 - Adult spring chinook salmon arrived at Dworshak NFH between 26 May 1989 and 14 September 1989. During spawning the fish were anesthetized using Tricaine Methanesulfonate (MS-222) at 100 mg/l buffered with bicarbonate. All adults used for the study were inoculated twice with erythromycin phosphate (11 mg/kg- dorsal sinus) prior to spawning.

Adult spring chinook salmon were tested for the prevalence of *Renibacterium salmoninarum* using enzyme-linked immnosorbant assay (ELISA) (Pascho and Mulcahy 1987). Eggs spawned from parents with optical density unit (ODU) readings (either parent) greater than 0.5 were designated high for bacterial kidney disease (BKD). Only eggs spawned from parents with ODU readings (either parent) less than 0.5 were used in the study.

Eggs were incubated in vertical incubation stacks. Green eggs were placed in Heath trays and water hardened for 30 minutes in 75 mg/l iodophor buffered with sodium bicarbonate. Eggs were incubated in ambient water (12^{o}C) with a water flow of 19 l/min. Hatching was completed by mid-October. Swim-up occurred from 12 November 1989 to 7 December 1989.

Sac fry were moved from Heath trays to nursery tanks (2.5 m^3) beginning in early November. Fry from five or six Heath trays were placed in each tank so that the average density was about 26,000 fish per tank. Biodiet #2 and #3 were used for initial feeding and fish were fed by hand eight times daily.

The fish were moved from the nursery to single pass flow-through raceways on 20 April 1990. Prior to being moved, each nursery tank was inventoried. An inventory of fish in each tank was obtained by taking a random sample of fish, obtaining a sample weight, counting the number of fish in the sample, and then calculating the number of fish per pound. This was repeated three times to obtain a mean tank sample count of fish per pound. All the fish in each nursery tank were then weighed and an estimate of the total number of fish in the tank was calculated. At the time of transfer, fish averaged 185 fpp. Fish were initially loaded at double the final rearing density and were split to their final rearing densities on 24 July 1990 at 75 fpp. All study fish received two treatments of erythromycin. Treatments were 21 days in duration; the first feeding began 2 July 1990 and the second feeding began 10 October 1990. Fish were fed Oregon Moist Pellets by hand during outside rearing. Mortalities were removed and enumerated daily. All fish were directly released into the North Fork of the Clearwater River at Dworshak NFH on 4 April 1991 at a size of about 20 fish per pound.

Brood Year 1990 - Adult spring chinook salmon arrived at Dworshak NFH between 18 May and 10 September 1990. During spawning the fish were anesthetized using MS-222 at 100 mg/l buffered with bicarbonate. Adults that returned to the complex three weeks prior to first spawning were inoculated on two different occasions with erythromycin phosphate (20 mg/kg-dorsal sinus) prior to spawning. Those returning from one to three weeks prior to first spawning received one inoculation, while those returning less than one week before spawning were not inoculated.

Adults were tested for the prevalence of *R. salmoninarum* similar to broodyear 1989 (BY89). Only eggs spawned from parents with ODU readings less than 0.5 were used in the study. Eggs were incubated in vertical incubation stacks. Green eggs were placed in Heath trays (eggs from one female per tray) and water hardened for 30 minutes in 75 mg/l iodophor buffered with sodium bicarbonate, similar to BY89. Eggs were incubated in ambient water (10-12^{o}C) with a water flow of 19 l/min. Hatching was completed by mid-October and swim-up occurred during the period 21 November 1990 to 28 November 1990.

Fry were moved from incubator stacks to nursery tanks when approximately 50 percent of the fry had attained swim-up. Fry from take six were transfered to tanks 19-20 November 1990. Fry from take seven were transfered to tanks 26 November 1990.

Fingerlings were moved to outside raceways from 14-16 May 1991 at double the final rearing densities. Sixteen tanks of low-density fish were moved to five raceways at 30,500 to 32,000 fish per raceway. Nine tanks of medium-density fish were transferred to three raceways at 60,000 to 63,500 fish per unit. Six tanks of high-density fish were moved to two raceways at 86,500 fish per unit. Initial raceway water flows averaged 1,289 l/min.

From 1 May 1991 to 21 May 1991 a prophylactic 21-day treatment of erythromycin was fed. A second erythromycin feeding was given from 24 September 1991 through 11 October 1991. Fish were released directly into the North Fork of the Clearwater River at Dworshak NFH on 15-16 April 1992 at a size of about 15 fish per pound.

Experimental Design

The study was conducted for two years (BY89 and BY90). Normal rearing density in outside raceways is 45,000 fish/raceway. Three rearing densities were tested: 1) low density or 1/3 normal loading at 15,000 fish per raceway; 2) medium density or 2/3 normal loading at 30,000 fish per raceway; and 3) high density or normal loading at 45,000 fish per raceway. For BY89, the experiment was started when fingerlings were transferred from the nursery to outside raceways. A total of nine raceways were set up at low density, six raceways at medium density, and three raceways at high density.

For BY90, the experiment was started in the nursery when sac fry were transferred from Heath trays to nursery tanks. Nursery tanks were loaded to test three rearing densities: 1) low density or 1/3 normal loading at 11,000 fish per tank; 2) medium density or 2/3 normal loading at 22,000 fish per tank; and 3) high density or normal loading at 33,000 fish per tank. All fingerlings were transferred to outside raceways and were loaded similar to BY89. Fingerlings reared at low, medium and high densities in the nursery were used set up the comparable low, medium, and high density experiments in raceways.

To determine if rearing density affected smolt survival to Lower Granite Dam or adult returns to the hatchery, the following two hypotheses were tested:

1. H_o: Post-release survival rates to Lower Granite Dam for spring chinook salmon smolts reared at low, medium, and high densities are not significantly (P>.05) different, $S_1 = S_2 = S_3$.

   H_a: Post-release survival rates to Lower Granite Dam for spring chinook salmon smolts reared at low, medium, and high densities are significantly (P<.05) different, $S_1 \neq S_2 \neq S_3$.

2. H_o: The smolt to adult return rates for spring chinook salmon reared at low, medium, and high densities are not significantly (P>.05) different, $S_1 = S_2 = S_3$.

   H_a: The smolt to adult return rates for spring chinook salmon reared at low, medium, and high densities are significantly (P<.05) different, $S_1 \neq S_2 \neq S_3$.

Smolt Survival During Outmigration

To test Hypothesis No. 1, 1500 fish in each of the three density groups for BY89 were marked with PIT tags in February 1991 by the Idaho Department of Fish and Game (IDFG). For BY90, 600 fish in each of the three density groups were marked with PIT tags by the USFWS Lower Columbia River Fishery Resource Office (LCRFRO) in February 1992. Survival of smolts to Lower Granite Dam was estimated by using PIT-tag interrogation rates. Interrogation rates at Lower Granite, Little Goose, and McNary dams were accumulated and used as a minimum estimate of survival to Lower Granite Dam. A chi-square test for goodness-of-fit (uniform distribution) was used to compare interrogation rates between density groups for both years (Conover 1971).

Smolt to Adult Survival

To test Hypothesis No. 2 for BY89, the IDFG coded-wire tagged 147,328 fish reared at low density, 199,162 fish reared at medium density, and 150,721 fish reared at high density during November and December 1990. For BY90, LCRFRO coded-wire tagged 147,226 in the low density group, 186,822 in the medium density group, and 152,352 in the high density group in June 1991. For both broodyears, each experimental raceway received a unique coded-wire tag to evaluate adult returns.

Smolt-to-adult survival was estimated using coded-wire tag return data. Percent yield (smolt to adult return rate) was calculated by dividing the total number of coded-wire tagged adults that returned to each raceway by the number of coded-wire tagged smolts released, multiplied by 100. These proportions were normalized by performing a square root-arcsin transformation (Zar 1984). Analysis of Variance (ANOVA) was then used to determine if mean yield was significantly different between density groups (Wilkinson 1990). Post-hoc pair-wise comparisons of means were made using the Tukey Honestly Significant Difference (HSD) Test (Wilkinson 1990). ANOVA was also used to determine if there were significant differences in the mean number of adults returning per raceway between density groups (Wilkinson 1990). The Tukey HSD Test was used for post-hoc pair-wise comparisons of means.

Rearing Mortality Rates

For both brood years, total monthly mortality during hatchery rearing for each density group was calculated by summing the daily mortalities for each raceway in each respective density group for each month. Monthly mortality rates were calculated by dividing the total monthly mortality in each density group by the total number of fish in each density group at the beginning of each month.

Fish Health

The prevalence of *R. salmoninarum* in juvenile populations during raceway rearing was determined for both brood years using ELISA (Pascho and Mulcahy 1987). ELISAs were performed on a monthly basis from December 1990 to April 1991 and November 1991 to April 1992 for BY89 and BY90, respectively. ELISA data (ODUs) were converted to logarithms to reduce variability for statistical analysis (Zar 1984). ANOVA was used to determine if mean monthly ODU values were significantly ($P<.05$) different (Wilkinson 1990). Post-hoc pair-wise differences in means were compared between densities using the Tukey HSD Test (Wilkinson 1990).

Migration Time

Migration times from Dworshak NFH to Lower Granite, Little Goose, and McNary dams were determined using PIT-tag interrogation data at each facility. Mean migration times were compared between density groups for both years using ANOVA (Wilkinson 1990). For those cases where significant differences were observed, post-hoc pair-wise differences in means were compared using theTukey HSD Test (Wilkinson 1990).

Extended Seawater Rearing

On 27 March 1991, 60 BY89 spring chinook salmon smolts were collected from each of the three high density raceways and from three of the low density raceways. On 15 April 1992, 60 BY90 spring chinook salmon smolts were collected from each of the three high density raceways, three of the medium density raceways, and three of the low density raceways. All groups were transfered to Marrowstone Field Station as a part of an onging research project to evaluate the quality of hatchery reared salmon smolts using standardized seawater rearing techniques. Details about transportation to Marrowstone, fish culture, and data analysis are reported in Palmisano (1994).

Results

Smolt Survival During Outmigration

Interrogation rates for BY89 smolts were similar between density groups (Figure 2). The percentage of PIT-tagged smolts that were interrogated ranged from 48% for one of the medium density raceways to 57% for one of the low density raceways (Table 1). The medium density group as a whole had the fewest interrogations and the lowest overall interrogation rate, 49%, although there was no significant (P>0.9) difference between density groups.

Interrogation rates for BY90 smolts differed markedly from BY89 (Figure 2). The percentage of PIT-tagged smolts that were interrogated ranged from 36% for one high density raceway to 59% for one of the low density raceways (Table 2). Overall, interrogation rates were 57%, 53%, and 39% for the low, medium, and high density groups, respectively, and were significantly (P<0.05) different.

Smolt to Adult Survival

For BY89, the low density group had the highest percent yield, 0.043%. The high density group had a higher percent yield than the medium density group, 0.031% (Table 3). However, differences between groups were not significant (P>0.3).

In contrast, the mean number of adults that returned per raceway was significantly (P<0.015) different between density groups. The low density group returned an average of 7 adults per raceway while the medium and high density groups returned means of 9 and 15 adults per raceway, respectively (Table 3). Post-hoc pair-wise comparisons indicated that only the low and high density groups were significantly different. Thus, percent yield and mean number of adults returning per raceway gave different results.

For BY90, only 10 coded-wire tagged adults returned. Percent yield was the highest for the medium density group, 0.004% (Table 3). This was twice that for the low density group and four times greater than the high density group. Because the data were limited, no statistical analysis was performed.

Rearing Mortality Rates

<u>Brood Year 1989</u> - Mean monthly mortality rates ranged from 0.001 to 0.004, 0.001 to 0.005, and 0.001 to 0.006 for the low, medium and high density groups, respectively (Tables 4, 5, and 6). The trend in mortality over the rearing period was similar among all three groups with two exceptions. Medium density fish did not experience the increase in mortality during July 1990 that low and high density fish experienced. Low density fish experienced a slight increase in mortality during March 1991 unlike medium and high density fish (Figure 3). Mortality rates were highest immediately after fingerlings were stocked into raceways and decreased steadily up to the time of release.

Brood Year 1990 -Mean monthly mortality rates did not appear to vary much between the low and medium density groups. Rates ranged from .001 to .013 and from .001 to .012 for the low and medium density groups, respectively (Tables 7 and 8). However, fish in the high density group experienced noticeably higher mortalities ranging from .001 to .047 (Table 9). During December 1990, after fish were moved out of the nursery tanks and into the outside raceways, fish in the high density experiment had a mortality rate of .047, 3.4 times higher than fish in the low or medium density experiments. From January to August 1991, mortalities were similar among all three groups. However, from September 1991 to April 1992, the high density group had noticeably higher mortalities than the low or medium density groups (Figure 3).

Fish Health

Generally, ODU did not exhibit any consistent trends for BY89 and no clear pattern of *R. salmoninarum* prevalence was observed for any one density group (Figure 4). However, the high density group for BY90 showed a consistent trend of higher *R. salmoninarum* levels throughout the rearing period (Figure 4). The high density group always had significantly higher ODU values than low or medium density groups and were generally in the category of infection considered 'high', ODU>0.499 (Table 10). Overall, ODU values were higher for BY90 compared to BY89.

Migration Time

Migration time for all three density groups from Dworshak NFH to the IDFG smolt trap at the mouth of the Clearwater River was about one day (55 km/day) for both BY89 and BY90. Migration times increased significantly between the Clearwater River smolt trap and Lower Granite Dam, the first mainstem PIT-tag interrogation facility on the lower Snake River. For both BY89 (Table 12) and BY90 (Table 13), migration times were longer for the low density groups. The high density groups had the shorter migration times to each interrogation facility both years. Migration time patterns were consistent between densities for both years although BY90 smolts traveled faster than BY89 smolts (Figure 5).

Migration times were significantly different ($P<.05$) between densities for both BY89 and BY90, except for times to McNary Dam. Post-hoc tests between means revealed that low density groups had consistently significantly ($P<.05$) longer migration times to Lower Granite Dam, while medium and high density groups were not significantly different. For migration times to Little Goose Dam, low density groups had significantly ($P<.05$) longer migration times than high density groups but differences between low and medium density groups and medium and high density groups were not significant.

Extended Seawater Rearing

Mortality rates of test lots of fish during extended seawater rearing were different between years. The mean cumulative mortality rate for the BY89 low and high density groups were 48.9% and 47.3%, respectively (Table 14). No statistically significant differences were observed between treatment groups although the high density replicate from Raceway 26 had a substantially higher rate than the other replicates. The primary cause of mortality in Raceway 26 was BKD.

The mean cumulative mortality rate for the BY90 low, medium, and high density groups were 45.4%, 45.1%, and 80.1%, respectively (Table 15). The high density replicates experienced significantly ($P<.05$) higher mortality than the other two treatment groups. Raceway 26 had the highest mortality rate of the three high density replicates, the primary cause of death was attributed to BKD. These results correspond very closely to what we observed during hatchery rearing.

Discussion

Previous research by Banks (1994) showed a significant reduction in post-release survival of spring chinook smolts as rearing density increased. Consistently significant reductions in survival with increased density were found within four brood years tested. Increased rearing density failed to produce significant increases in adult contributions. In contrast to the consistent inverse relationship between rearing density and survival in the Banks (1994) study, there was no significant difference in outmigration survival rates between density groups for BY89 smolts or for the low and medium density groups for BY90 smolts at Dworshak NFH. The BY90 high density group was the only group that exhibited significantly lower post- release survival.

Rearing Mortality Rates

The high density group in BY90 did not perform as well as the other groups for reasons that were not readily apparent. Although the BY90 high density group experienced higher rearing mortality than the other groups, there was no consistent trend in the pattern of mortality between density groups as was observed by Banks (1994). If the densities tested were having an affect on mortality rate, we failed to see it with BY89 and with the medium and low density groups for BY90.

Fish Health

Based on the ODU data, the high mortality rate of the BY90 high density group during raceway rearing was probably due to BKD. The higher prevalence of *R. salmoninarum* may have been influenced by increased stress as a result of high density. However, an examination of the individual raceway mortality records for the BY90 high density group does not show a consistent pattern of high mortality across all experimental units. The BY90 high density experiment was conducted in three separate raceways. Of the total mortalities for the high density group from 1 June 1991 to 1 March 1992, about 60 percent occurred in one raceway, 30 percent in the second, and 10 percent in the third (Table 15). If the mortality rate were due to density, it would be reasonable to expect the mortality to be less disproportionately distributed.

When the density experiments were initiated in the nursery in 1990, individual nursery tank populations were not taken randomly from the total population of button-up fry. Although no eggs from females with ODU greater than 0.5 were used in the study, one or more females could have made a disproportionate contribution to particular nursery tanks. If some females had higher levels of *R. salmoninarum* (0.4 vs 0.1, for example), progeny from those females with different *R. salmoninarum* levels could possibly exhibit different propensities for mortality. This could explain the disproportionate mortality rates between the high density raceways for BY 1990 and the consistently lower performance of the high density group overall. In the final analysis, we could not show any consistent relationship between rearing density and the level of infection by *R. salmoninarum*.

Migration Time

Theoretically, a slower migration time would expose fish to higher levels of predation and competition for food. If that were the case, then the low density groups should have had lower interrogation rates than the high density groups since the low density groups traveled slower. Actually, migration time was not related to interrogation rate for BY89 smolts. Even though the high density group traveled faster than the low density group, both groups had similar interrogation rates. The BY90 high density group traveled faster than either the low or medium density group but actually has a lower interrogation rate. We could not find a consistent relationship between migration time and post-release survival during downriver migration.

Extended Seawater Rearing

The research being conducted by Marrowstone Field Station is designed to emulate as closely as possible the entry of smolts into the ocean environment. By rearing smolts in seawater for extended periods of up to six months, researchers try to evaluate smolt performance. Representative groups from the BY89 and BY90 rearing density study were used by Marrowstone for their research and provided some very interesting results. Basically, the same patterns of mortality during hatchery rearing and post-release survival for both BY89 and BY90 were observed during extended seawater rearing experiments. In fact, the BY90 high density group in raceway 26 had the highest mortality rate of the three high density raceways at both the hatchery and at Marrowstone.

Conclusions

First, only two years of data are available for analysis of hatchery and post-release performance. Only one year of data was sufficient for examining adult returns. An unaccountable source of bias may have been introduced into the experimental design when the various rearing density groups being compared were not drawn from the total population. When the groups were set up in the outside raceways in 1990, the fingerlings used were not all part of the total population coming out of the nursery. Similarly, when the groups were set up in the nursery tanks in 1990, the button-up fry used were not all part of the same population. When these fish were moved from the nursery to outside raceways in 1991, the same mistake made in 1990 was repeated. In addition, the time and size at release were different between years and may also have has an influence on the results.

Given the qualifications outlined above, three general conclusions can be made from this study:

1. Data were insufficient to conclude if the rearing densities we tested at Dworshak NFH had any consistent influence on hatchery performance, post-release performance as measured by PIT-tag interrogation rates, or adult returns.

2. Although the performance of the BY90 high density group was much lower than the other groups, a detailed analysis of the individual raceway mortality records and extended saltwater rearing trials failed to demonstrate a consistent relationship between rearing density and performance.

3. The BY89 high density group produced significantly more adults per raceway than the low density group, despite the fact that the low density group had the highest yield. In a program where success is measured by the number of adults returned, the best production strategy to employ may be the one that returns the most adults, not necessarily the one that has the highest yield. Low density may give a higher yield, but because fewer smolts are released, fewer adults return. A higher density may result in a lower yield, but the higher number of smolts released may compensate for that and actually give you a higher adult return.

Recommendations

1. We cannot recommend any change in the originally designed rearing density of 45,000 fish per raceway, at a release size of 20 fish per pound. For the past several years, it has been very difficult to meet the size at release goal of 20 fish per pound without putting the fish on a restricted diet. Two years ago the HET evaluated the situation and recommended against using this type of strategy to meet the size at release goal. Therefore, spring chinook salmon are generally about 15 fish per pound or bigger at the time of release. Assuming that size at release will continue to be about 15 fpp, the rearing density should be adjusted to about 34,000 fish per raceway. If all 40 raceways are stocked at this density, the program would call for a total of about 1,350,000 juvenile chinook salmon. Assuming a 10% mortality rate during outside raceway rearing, the total release would be about 1,215,000, slightly over the number called for in Appendix B of the Columbia River Fisheries Management Plan. During those years when returns are insufficient to meet the broodstock needs required for the program, rearing densities should be lowered accordingly.

2. This study has provided valuable information for the program but should not be considered any more than a pilot study. Results from this work should be used to help design a long term project to evaluate rearing density. Evaluations should be based not on the number of fish per container, but on Density and Flow Indices.

Literature Cited

Banks, J.L. 1990. A review of rearing density experiments: Can hatchery effectiveness be improved? Pages 94-102 in Status of future of spring chinook salmon in the Columbia River Basin - conservation and enhancement. National Oceanic and Atmospheric Administration, Technical Memorandum NMFS, F/NWC-187. Northwest Fisheries Science Center, Seattle, Washington.

Banks, J.L. 1992. Effects of density and loading on coho salmon during hatchery rearing and after release. Progressive Fish Culturist 54:137-147.

Banks, J.L. 1994. Raceway density and water flow as factors affecting spring chinook salmon during rearing and after release. Aquaculture 119:201-217.

Banks, J.L. and L. G. Fowler. 1982. The effects of population weight loads and crowding on fall chinook fingerlings reared in circular tanks. Abernathy Salmon Culture Development Center, U.S. Fish Wildlife Service, Technical Transfer Series No. 82-3, 12 pp.

Conover, W.J. 1971. Practical non-parametric statistics. John Wiley and Sons, New York, New York.

Denton, C. 1988. Marine survival of chinook salmon, *Oncorhynchus tshawytscha*, reared at three densities. Alaska Department of Fish and Game, FRED Report 88, Anchorage, Alaska.

Downey, T., G. Susac, and J. Nicholas. 1988. Research and development of Oregon's coastal chinook stocks. Oregon Department of Fish and Wildlife Annual Progress Report, Project No. AA-87-ABD-00109 (unpubl.), 28 pp.

Ewing, R., E. Birks, A. Hemmingsen, and J. Dentler. 1981. Effects of fish population density on selected physiological processes. Oregon Department of Fish and Wildlife Annual Progress Report, Project No. F-104-R-2 (unpubl.), 98 pp.

Ewing, R.D. and S.K. Ewing. 1995. Review of the effects of rearing density on survival to adulthood for pacific salmon. Progressive Fish Culturist 57:1-25.

Fagerlund, U.H.M., J.R. McBride, B.S. Dosanjh, H.T. Bilton, R.B. Morley, and J. Van Tine. 1984. Density effects on performance to release of three size groups within populations of pond-reared juvenile coho salmon. Smolts released from Quinsam Hatchery in 1983. Canadian Technical Report of Fisheries and Aquatic Sciences 1337.

Fagerlund, U.H.M., J.R. McBride, B.S. Dosanjh, and E.T. Stone. 1987. Culture density and size effects on performance to release of juvenile chinook salmon and subsequent ocean survival. Smolt releases from Capilano Hatchery in 1980 and 1981. Canadian Technical Report of Fisheries and Aquatic Sciences 1572.

Fagerlund, U.H.M., J.R. McBride, B.S. Dosanjh, E.T. Stone, and F.K. Sandercock. 1983. Influence of culture density on juvenile coho salmon production and ocean survival. Smolt releases in 1979 and 1980 from Capilano Hatchery. Canadian Technical Report of Fisheries and Aquatic Sciences 1229.

Fagerlund, U.H.M., J.R. McBride, and E.T. Stone. 1981. Stress-related effects of hatchery rearing density on coho salmon. Transactions of the American Fisheries Society 110:644-649.

Hemmingsen, A., J. Westgate, and J. Conrad. 1979. Coho salmon pond loading study. Oregon Department of Fish and Wildlife Annual Progress Report, Project No. AFC-77-3 (unpubl.), 32 pp.

Martin, R.M. and A. Wertheimer. 1989. Adult production of chinook salmon reared at different densities and released at two smolt sizes. Progressive Fish Culturist 51:194-200.

Palmisano, A.N. 1994. Standardized seawater rearing to evaluate the effects of freshwater rearing densities on spring chinook salmon at Dworshak National Fish Hatchery. Progress Report. Marrowstone Field Station, National Fishery Research Center, Seattle, Washington.

Pascho, R.J. and D. Mulcahy. 1987. Enzyme-linked immunosorbant assay for a soluble antigen of *R. salmoninarum*, the causative agent of bacterial kidney disease. Canadian Journal of Fisheries and Aquatic Science 44:183-191.

Patino, R., C. Schreck, J.Banks, and W. Zaugg. 1986. Effects of rearing conditions on the developmental physiology of smolting coho salmon. Transactions of the American Fisheries Society 115:828-837.

Refstie, T. and A. Kittelsen. 1976. Effect of density on growth and survival of artificially reared Atlantic salmon. Aquaculture 8:319-326.

Sandercock, F.K. and E.J. Stone. 1982. A progress report on the effect of rearing density on subsequent survival of Capilano coho. In: B.R. Melteff and R.A. Neve (Editors), Proceedings of the North Pacific Aquaculture Symposium, August 1980, Anchorage, Alaska. Alaska Sea Grant Report 82-2, p. 151.

Schreck, C. R. Patino, C. Pring, J. Winton, and J. Holway. 1985. Effects of rearing densities on indices of smoltification and performance of coho salmon, *Oncorhynchus kisutch*. Aquaculture 45:345-358.

U.S. Army Corps of Engineers. 1981. Lower Snake River Fish and Wildlife Compensation Plan. Destan Memorandum. No. 9: Dworshak National Fish Hatchery Expansion-Spring chinook rearing.

Wilkinson, L. 1990. SYSTAT: The system for statistics. Evanston, Illinois. SYSTAT, Inc., 1990.

Zar, J.H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J.

ble 1. Number (No.) and percentage (%) of PIT-tagged spring chinook salmon released from Dworshak NFH in 1991 (BY89) th
e interrogated at Lower Granite (GRJ), Little Goose (GOJ), and McNary (MCJ) dams.

		Number	GRJ		GOJ		MCJ		Total	
ceway	Density	Released	No.	%	No.	%	No.	%	No.	%
7	Low	500	144	29	70	14	29	6	243	49
8	Low	501	173	35	85	17	29	6	287	57
9	Low	502	143	28	78	16	31	6	252	50
12	Med	501	161	32	56	11	26	5	243	49
13	Med	501	148	30	61	12	31	6	240	48
14	Med	500	156	31	68	14	23	5	247	49
24	High	500	154	31	71	14	28	6	253	51
26	High	500	143	29	81	16	25	5	249	50
27	High	502	169	34	71	14	37	7	277	55
tal	Low	1503	460	31	233	16	89	6	782	52
tal	Med	1502	465	31	185	12	80	5	730	49
tal	High	1502	466	31	223	15	90	6	779	52

ble 2. Number (No.) and percentage (%) of PIT-tagged spring chinook salmon released from Dworshak NFH in 1992 (BY90) th
e interrogated at Lower Granite (GRJ), Little Goose (GOJ), and McNary (MCJ) dams.

		Number	GRJ		GOJ		MCJ		Total	
ceway	Density	Released	No.	%	No.	%	No.	%	No.	%
7	Low	200	67	34	26	13	20	10	113	57
8	Low	200	78	39	21	11	19	10	118	59
9	Low	200	73	37	26	13	14	7	113	57
10	Med	200	72	36	26	13	19	10	117	59
11	Med	200	66	33	21	11	12	6	99	50
12	Med	200	55	28	29	15	16	8	100	50
26	High	200	64	32	13	7	3	2	80	40
29	High	200	40	20	23	12	8	4	71	36
30	High	200	51	26	19	10	13	7	83	42
tal	Low	600	218	36	73	12	53	9	344	57
tal	Med	600	193	32	76	13	47	8	316	53
tal	High	600	155	26	55	9	24	4	234	39

ble 3. Number of coded-wire tags recovered for each age group of adult spring chinook salmon returning to Dworshak NFH by sity and release year.

elease ear	Density	CWT Fish Released	0-Salts [1]	CWT I-Salts	Recoveries II-Salts	III-Salts	Total Returns	Percent Yield	Mean Raceway Return
991	Low	145,418	0	0	55	8	63	0.043	7
	Med	196,880	0	1	52	3	56	0.028	9
	High	146,734	0	2	39	4	45	0.031	15
992	Low	141,437	4	0	2	1	3	0.002	0.3
	Med	169,593	10	2	4	0	6	0.004	1
	High	121,664	2	0	1	0	1	0.001	0.3

ish that were released but failed to migrate to the ocean.

Table 4. Numbers[1], mortality, mortality rate, and number of additional fish removed from low density raceways each month for Brood Year 1989 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
04-20-90	162,114	610	.004	0
05-01-90	161,504	272	.002	20
06-01-90	161,212	228	.001	30
07-01-90	160,954	428	.003	30
08-01-90	160,496	145	.001	0
09-01-90	160,351	144	.001	65
10-01-90	160,142	314	.002	65
11-01-90	159,763	234	.001	107
12-01-90	159,422[3]	135	.001	30
01-01-90	159,257	102	.001	60
02-01-90	159,095	114	.001	30
03-01-90	158,951	236	.001	385
04-01-90	158,330	36	N/A	0
04-04-90	158,294[4]			

[1] Numbers of fish each month from 04-20-90 to 11-1-90 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the monthly mortality, and he additional fish removed.
[2] Fish removed from raceways for fish health exams, ATPase levels, salt water challenge, etc., that are not considered natural mortality.
[3] Actual inventory number derived when fish were coded-wire tagged and inventoried during November. Six raceways completed by 11-29-90 and three raceways completed by 12-01-90.
[4] Total number released.

Table 5. Numbers[1], mortality rate, and number of additional fish removed from medium density raceways each month for Brood Year 1989 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
04-20-90	211,036	1,040	.005	0
05-01-90	209,996	371	.002	20
06-01-90	209,605	251	.001	10
07-01-90	209,344	251	.001	0
08-01-90	209,093	165	.001	10
09-01-90	208,918	165	.001	20
10-01-90	208,733	411	.002	20
11-01-90	208,302	251	.001	20
12-01-90	208,031[3]	138	.001	20
01-01-91	207,873	94	>.001	20
02-01-91	207,759	104	.001	50
03-01-91	207,605	88	>.001	60
04-01-91	207,457	23	N/A	
04-04-91	207,434[4]			

[1] Numbers of fish each month from 04-20-90 to 11-01-90 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the monthly mortality, and the additional fish removed.
[2] Fish removed from raceways for fish health exams, ATPase levels, salt water challenges, etc., that are not considered natural mortality.
[3] Actual inventory number derived when fish were inventoried and coded-wire tagged in November.
[4] Total number released.

Table 6. Numbers[1], mortality, mortality rate, and numbers of additional fish removed from the high density raceways each month for Brood Year 1989 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
04-18-90	155,361	917	.006	0
05-01-90	154,444	564	.004	10
06-01-90	153,870	207	.004	10
07-01-90	153,653	567	.003	0
08-01-90	153,086	261	.002	0
09-01-90	152,825	130	.001	10
10-01-90	152,685	244	.002	0
11-01-90	152,441	321	.002	10
12-01-90	152,110[3]	140	.001	20
01-01-91	151,970	98	.001	0
02-01-91	151,872	101	.001	10
03-01-91	151,761	76	.001	116
04-01-91	151,569	20	N/A	385
04-01-91	151,164[4]			

[1] Numbers of fish each month from 04-20-90 to 11-01-90 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the monthly mortality, and the additional fish removed.
[2] Fish removed from raceways for fish health exams. ATPase levels, salt water challenges, etc., that are not considered natural mortality.
[3] Actual inventory number derived when fish were coded-wire tagged and inventoried during November.
[4] Total number released.

Table 7. Numbers[1], mortality, mortality rate, and numbers of additional fish removed from low density nursery tanks and raceways each month for Brood Year 1990 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
12-01-90[3]	154,085	2,072	.013	0
01-01-91	152,013	1,334	.009	0
02-01-91	150,679	735	.005	0
03-01-91	149,944	897	.006	0
04-01-91	149,047	928	.006	0
05-15-91[4]	148 119	843	.006	0
06-15-91[5]	147,276[6]	249	.002	0
07-01-91	147,027	80	.001	0
08-01-91	146,947	140	.001	0
09-01-91	146,807	110	.001	0
10-01-91	146,697	312	.002	156
11-01-91	146,229	32	.001	45
12-01-91	146,152	42	>.001	0
01-01-92	146,110	63	>.001	0
02-01-92	146,047	77	>.001	255
03-01-92	145,715	81	.001	0
04-01-92	145,634	77	.001	265
04-16-92	145,292[7]	--	--	--

[1] Numbers of fish each month from 12-01-90 to 05-19-91 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the monthly mortality, and the additional fish removed.
[2] Fish removed from raceways for fish health exams. ATPase levels, salt water challenges, etc., that are not considered natural mortality.
[3] Start of low density experiments in nursery tanks.

[4] Fingerlings were moved from indoor nursery tanks to five outside raceways.
[5] Start of low density experiments in outside raceways.
[6] Actual inventory derived during coded-wire tagging activity.
[7] Total number released.

Table 8. Numbers[1], mortality, mortality rate, and number of additional fish removed from medium density nursery tanks and raceways each month for Brood Year 1990 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
12-01-90[3]	194,765	2,377	.012	0
01-01-91	192,388	2,273	.012	0
02-01-91	190,115	948	.005	0
03-01-91	189,167	833	.004	0
04-01-91	188,334	652	.003	0
05-15-91[4]	187,682	860	.005	0
06-15-91[5]	186,822[6]	193	.001	0
07-01-91	186,629	112	.001	0
08-01-91	186,517	147	.001	0
09-01-91	186,370	819	.004	0
10-01-91	185,551	532	.003	34
11-01-91	184,985	362	.002	0
12-01-91	184,623	646	.003	0
01-01-92	183,977	464	.003	0
02-01-92	183,513	482	.003	120
03-01-92	182,911	681	.004	0
04-01-92	182,230	361	.002	180
04-16-92	181,689[7]	--	--	--

[1] Numbers of fish each month from 12-01-90 to 05-19-91 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the

monthly mortality, and the additional fish removed.
[2] Fish removed from raceways for fish health exams. ATPase levels, salt water challenges, etc., that are not considered natural mortality.
[3] Start of low medium density experiments in nursery tanks.
[4] Fingerlings were moved from indoor nursery tanks to three outside raceways.
[5] Start of medium density experiments in outside raceways.
[6] Actual inventory number derived during coded-wire tagging activity.
[7] Total number released.

Table 9. Numbers[1], mortality, mortality rate, and number of additional fish removed from high density nursery tanks and raceways each month for Brood Year 1990 spring chinook salmon at Dworshak NFH, Idaho.

Date	Number of Fish	Mortality	Mortality Rate	Additional Fish Removed[2]
12-01-90[3]	166,415	7,878	.047	0
01-01-91	158,537	2,525	.016	0
02-01-91	156,012	1,076	.007	0
03-01-91	154,936	842	.005	0
04-01-91	154,094	916	.006	0
05-15-91[4]	153,178	826	.005	0
06-15-91[5]	152,352[6]	188	.001	0
07-01-91	152,164	304	.002	0
08-01-91	151,860	435	.003	0
09-01-91	151,425	4,248	.028	0
10-01-91	147,177	2,273	.015	114
11-01-91	144,790	1,361	.009	45
12-01-91	143,384	2,571	.018	0
01-01-92	140,813	2,130	.009	0
02-01-92	138,683	2,389	.017	255
03-01-92	136,039	3,477	.026	0
04-01-92	132,562	1,785	.013	310

04-16-92	130,467[7]	--	--	--

[1] Numbers of fish each month from 12-01-90 to 05-19-91 are adjusted numbers derived by back calculating using the inventory number obtained during the coded-wire tagging activity, the monthly mortality, and the additional fish removed.
[2] Fish removed from raceways for fish health exams. ATPase levels, salt water challenges, etc., that are not considered natural mortality.
[3] Start of high density experiments in nursery tanks.
[4] Fingerlings were moved from indoor nursery tanks to three outside raceways.
[5] Start of high density experiments in outside raceways.
[6] Actual inventory number derived during coded-wire tagging activity.
[7] Total number released.

Table 10. Mean, variance, and standard deviation for ODU for spring chinook salmon at Dworshak NFH reared at three different densities.

Brood	Date	Density	N	Mean [1]	Variance	SD
1989	12/90	Low	16	0.071[a]	0.000	0.002
		Mod	10	0.072[a]	0.000	0.003
		High	5	0.072[a]	0.000	0.002
	01/91	Low	22	0.073[a]	0.000	0.004
		Mod	6	0.071[a]	0.000	0.002
		High	5	0.076[a]	0.000	0.004
	02/91	Low	18	0.076[a,b]	0.000	0.004
		Mod	30	0.080[b]	0.000	0.007
		High	30	0.075[a]	0.000	0.006
	03/91	Low	30	0129[a]	078	0.280
		Mod	30	0.061[b]	0.000	0.003
		High	30	0.070[b]	0.008	0.089
	04/91	Low	30	0.061[a]	0.000	0.004
		Mod	30	0.136[b]	0.100	0.316
		High	30	0.054[a]	0.000	0.007
1990	11/91	Low	15	0.092[a]	0.000	0.011
		Mod	13	0.103[a]	0.002	0.048
		High	5	0.550[b]	0.673	0.820
	12/91	Low	15	0.095[a]	0.000	0.016
		Mod	15	0.085[s]	0.000	0.004
		High	17	0.659[b]	0.602	0.776
	01/92	Low	28	0.085[a]	0.000	0.004
		Mod	30	0.086[a]	0.000	0.006
		High	27	0.233[b]	0.198	0.445
	02/92	Low	18	0.090[a]	0.000	0.005
		Mod	30	0.091[a]	0.000	0.013

	High	27	0.560^{b}	0.524	0.724
03/92	Low	30	0.092^{b}	0.000	0.010
	Mod	29	0.171^{a}	0.019	0.138
	High	30	0.245^{a}	0.229	0.479
04/92	Low	30	0.102^{a}	0.002	0.050
	Mod	29	0.087^{a}	0.000	0.012
	High	27	0.306^{b}	0.251	0.501

[1]Mean ODU values with different letters are significantly different at the .05 level.

Table 11. Number, (No.) monthly mortality, and monthly mortality rate for each raceway used in the high density experiment for Brood Year 1990 fish.

	Raceway 26			Raceway 29			Raceway 30		
Month	Number	Mortality	Percent	Number	Mortality	Percent	Number	Mortality	Percent
6-01-91	50,854	71	.001	50,280	39	.001	51,218	78	.002
07-01-91	50,783	165	.003	50,241	43	.001	51,140	96	.002
08-01-91	50,618	289	.006	50,198	31	.001	51,044	115	.002
09-01-91	50,329	2755	.055	50,167	331	.007	50,929	1162	.023
10-01-91	47,574	1428	.030	49,824	200	.004	49,755	645	.013
11-01-91	46,146	843	.018	49,624	103	.002	49,110	415	.008
12-01-91	45,303	1627	.036	49,521	223	.005	48,695	721	.015
01-01-92	43,676	1309	.030	49,298	221	.004	47,974	600	.013
02-01-92	42,367	1290	.030	48,942	287	.006	47,254	812	.017
03-01-92	41,077	1610	.039	48,655	526	.010	46,442	1341	.029
		Total	11,387		2004			5985	
		Pecent of Total	59%		10%			31%	

Table 12. Mean migration time (days) and mean migration rate (km/day) of PIT-tagged spring chinook salmon released from Dworshak NFH in 1991 that were interrogated at Lower Granite , Little Goose, and McNary dams.

		Lower Granite		Little Goose		McNary	
Racewa y	Density	Days	Km/Day	Days	Km/Day	Days	Km/Day
7	Low[1]	29.2	4.3	36.5	5.0	43.0	7.2
8	Low	28.9	4.3	35.8	5.1	41.0	7.6
9	Low	28.3	4.4	33.7	5.4	40.8	7.7
12	Med[2]	27.1	4.7	34.3	5.3	41.4	7.5
13	Med	28.3	4.4	34.2	5.4	41.5	7.5
14	Med	27.4	4.6	34.2	5.4	39.9	7.9
24	High[3]	27.2	4.7	33.8	5.5	39.6	7.9
26	High	26.5	4.8	32.2	5.7	39.9	7.8
27	High	26.6	4.7	33.9	5.3	40.2	7.7
Total	Low	28.8	4.4	35.3	5.2	41.6	7.5
Total	Med	27.6	4.6	34.2	5.4	41.0	7.6
Total	High	27.2	4.7	33.2	5.5	39.9	7.8

[1] 15,000 fish/raceway
[2] 30,000 fish/raceway
[3] 45,000 fish/raceway

Table 13. Mean migration time (days) and mean migration rate (km/day) of PIT-tagged spring chinook salmon released from Dworshak NFH in 1992 that were interrogated at Lower Granite, Little Goose, and McNary dams.

		Lower Granite		Little Goose		McNary	
Raceway	Density	Days	Km/Day	Days	Km/Day	Days	Km/Day
7	Low[1]	25.0	5.3	27.1	7.1	37.4	8.7
8	Low	22.2	5.9	26.4	7.1	35.5	9.0
9	Low	21.9	6.0	28.9	7.3	38.3	8.3
10	Med[2]	22.4	5.8	27.3	7.1	34.9	9.2
11	Med	20.9	6.1	29.4	7.1	32.9	10.0
12	Med	21.2	6.1	25.6	7.1	33.1	9.9
26	High[3]	19.9	6.4	24.8	7.0	31.1	9.9
29	High	20.4	6.3	26.1	7.3	32.9	9.7
30	High	19.8	6.5	23.8	7.4	31.5	10.1
Total	Low	23.0	5.7	27.5	7.3	36.9	8.7
Total	Med	21.5	6.0	27.2	7.5	33.8	9.6
Total	High	20.0	6.4	25.0	7.4	31.9	10.0

[1] 15,000 fish/raceway
[2] 30,000 fish/raceway
[3] 45,000 fish/raceway

Table 14. Cumulative percent mortality of BY89 spring chinook salmon reared at Dworshak NFH. Fish were transferred to full strength seawater on May 11, 1991.

	Low			High		
Date	A1	A2	A4	B24	B26	B27
04/06/91	0	1.7	1.8	0	0	0
04/13/91	0	5.3	1.8	1.9	0	0
04/20/91	0	12.9	1.8	1.9	2	0
04/27/91	0	12.9	1.8	1.9	2	0
05/04/91	0	15.1	1.8	1.9	2	0
05/11/91	0	15.1	1.8	1.9	2	0
05/18/91	0	15.1	1.8	1.9	2	0
05/25/91	0	15.1	1.8	1.9	2	0
06/01/91	0	15.1	1.8	1.9	2	0
06/08/91	0	17.7	1.8	1.9	2	0
06/15/91	0	17.7	1.8	1.9	2	0
06/22/96	0	17.7	7	1.9	4.6	0
06/29/91	2.6	17.7	12.2	1.9	7.2	0
07/06/91	2.6	17.7	12.2	4.5	20.1	2.6
07/13/91	2.6	20.3	12.2	7.1	22.7	2.6
07/20/91	2.6	20.3	12.2	10.1	35.1	2.6
07/27/91	2.6	20.3	12.2	10.1	50.6	5.6
08/03/91	2.6	20.3	15.2	10.1	59.9	5.6
08/10/91	2.6	23.4	21.3	13.1	59.9	8.6
08/17/91	2.6	26.5	21.3	13.1	63	11.6
08/24/91	2.6	26.5	24.3	16.1	66.1	11.6
08/31/91	5.6	26.5	24.3	16.1	72.3	14.6
09/07/91	14.5	29.6	27.3	19.1	72.3	14.6
09/14/91	17.5	32.7	30.3	22.1	72.3	17.6
09/21/91	20.5	38.8	36.4	25.1	72.3	23.5
09/28/91	26.4	48	39.4	25.1	72.3	26.5
10/05/91	29.4	48	39.4	25.1	72.3	29.5
10/12/91	29.4	48	42.4	25.1	72.3	29.5
10/19/91	29.4	48	42.4	28.1	72.3	29.5
10/26/91	41.2	51.1	42.4	28.1	72.3	29.5
11/02/91	41.2	51.1	42.4	34.1	72.3	29.5
11/09/91	41.2	51.1	42.4	34.1	72.3	29.5
11/16/91	50.1	54.2	42.4	37.1	72.3	32.5

Table 15. Cumulative percent mortality of BY90 spring chinook salmon reared at Dworshak NFH. Fish were transferred to full strength seawater on May 24, 1992.

	Low			Medium			High		
Thru Date	A7	A8	A9	A10	A11	A12	B26	B29	B30
04/18/92	0	0	0	0	0	0	0	0	0
04/25/92	0	0	0	0	0	0	0	0	0
05/02/92	1.8	0	0	0	0	0	0	0	0
05/09/92	1.8	0	0	0	0	0	4.1	6.4	0
05/16/92	1.8	0	0	0	0	0	8.2	12.8	7.7
05/23/92	1.8	0	0	0	0	0	8.2	15.6	10.1
05/30/92	6.4	4.8	9.8	2.4	0	4.8	10.8	18.4	24.7
06/06/92	11.6	7.5	12.6	10.5	2.6	4.8	23.1	28.6	27.6
06/13/92	11.6	7.5	12.6	10.5	2.6	4.8	41.6	32	27.6
06/20/92	11.6	10.2	12.6	13.2	10.3	4.8	72.4	35.4	33.4
06/27/92	22	15.6	18.2	18.6	18	4.8	87.8	49	39.2
07/04/92	22	21	18.2	21.3	23.1	18.4	94	52.4	45
07/11/92	35	31.9	23.8	43	28.2	32	97.1	66	50.8
07/18/92	35	36.3	26.6	43	28.2	40.2	97.1	66	65.3
07/25/92	35	53.7	30.1	43	31.3	43.7	97.1	72.8	70.3
08/01/92	38.3	53.7	37.1	53.7	34.4	43.7	97.1	72.8	70.3
08/08/92	38.3	60.7	37.1	53.7	34.4	47.2	97.1	72.8	70.3