Section 7

COORDINATING THE INTEGRATION OF NATURES VARIABLES INTO THE FORKS CREEK STUDY

by

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Introduction

New culture techniques must be developed for chinook salmon as less than 2% of these fish released from hatcheries survive to recruit to either the fishery or spawning population. Given that hatchery-produced salmon account for up to 80% of the fish in the fishery and that they are frequently the only source available for natural-run restoration, this is an unacceptably low survival rate. Fortunately there appears to be scope for improving hatchery-reared salmon postrelease survival, as their smolt-to-adult survival is much lower than that of wild-reared salmon. Salmonids produced with traditional fish culture techniques apparently lack many of the behavioral, physiological, and morphological characteristics needed to survive in the wild (see the review by Maynard et al. 1995). It may be possible to promote the expression of these wild characteristics by rearing salmon in a more natural hatchery environment.

Previous studies have been developing NATURES approaches consisting of seminatural raceway habitat, live food diets, exercise systems, predator avoidance training, underwater feed delivery systems, etc. (Maynard et al. 1995, 1996a, b, c, d). Seminatural raceway habitat composed of natural gravel substrates, artificial or natural vegetative structure, and overhead cover can be used to produce a more natural hatchery environment. In previous studies (Maynard et al. 1996c) and those described in this report the in-stream survival of chinook salmon reared in this NATURES raceway habitat was 25-50% higher than for fish reared in conventional raceways. It is unknown if this increase in in-stream survival leads to increased smolt-to-adult survival. Therefore in 1996, NMFS, Long Live the Kings (LLTK), WDFW, BPA, and the Weyerhaeuser Corporation initiated a multiyear production scale test to determine if rearing fall chinook salmon in seminatural raceway habitat also increased smolt-to-adult survival. The study was primarily funded by NMFS, WDFW, and LLTK. BPA participation was focused on coordinating information transfer of NATURES variables developed under BPA funding to the Forks Creek experiment. This section reports on the progress of the study through 1998.

Methods

The experimental facility was developed in 1996 with the installation of eight fiberglass raceways on a concrete pad at the WDFW Forks Creek Hatchery near Lebam, Washington. Forks Creek is a tributary of the Willapa River. The raceways (9.75 × 2.44 × 1.24 m high) maintained a water depth of 0.80 m. The interior of all eight raceways was originally dark gray (10 on the Kodak gray scale). In 1998, the interior of the control raceways was changed to a lighter shade of gray (2 on Kodak gray scale) to resemble the lighter color of concrete.

The control raceways were left unmodified for the most part. In all 3 years of operation, the top of each control raceway was covered with nine aluminum-frame panels (1.96 × 2.64 m) to prevent avian predation in the control tanks. The panels were fitted with white nylon netting (0.6 × 0.6 cm mesh) to prevent small predators, such as dippers (*Cinculus mexicanus*), from entering.

NATURES technology was transferred to the project so that the experimental raceways were fitted with resin rock paver substrate, a submerged Douglas fir tree structure, and covered with (U.S. military) camouflage netting. The resin rock pavers were tiles (0.6 × 0.6 m) fabricated with epoxy resin and river gravel (22 - 32 mm diameter). The river gravel was carefully selected to match the color of the sand and gravel found in Forks Creek. Structure was created by suspending five defoliated fir trees from a single horizontal cable running the length of each raceway, preventing them from touching the bottom. All needles were removed from each fir tree before weighting with rebar. The trees were suspended from the horizontal cable by vertical cables attached to each end of their trunk. Each free cable end was then attached to the horizontal cable with an interlocking spring snap so the trees could be easily moved or removed during cleaning. The raceways were covered with netting framed panels identical to the controls except a single layer of camouflage net was hung to provide 40% covered area along each side.

1997 Activities

In 1997, four experimental raceways were used for the study. On 24 February 1997, identical weights (approximately 54,000 fish) of fall chinook salmon swim-up fry were ponded into each raceway. The fish were reared following standard WDFW fish culture practices (Michak 1997). Each raceway was cleaned at least once every week with a commercial swimming-pool vacuum. All mortalities were counted and removed.

Every month a sample of 100 fish was removed from each raceway, weighed (to the nearest 0.001 g), measured (fork length to the nearest 1 mm), and means compared with *t*-tests. At least 30 fish in each sample were photographed with 400 ASA color slide film using a Nikon 8000S single lens reflex camera equipped with a micro lens (60 mm) and circular polarizing filter. The camera was mounted on a photographic light stand equipped with two quartz halogen lamps (300 W). The light was filtered through photographic gel to simulate daylight.

Before being photographed, the fish were anesthetized in MS-222 solution in black dishpans and then placed individually on a clear acrylic angled stand over a standardized blue background. The fish were photographed at least twice.

Each photograph was mounted in a standard plastic slide mount. This enabled it to be placed on a PVC plate (with the center drilled out) attached to the stage of a stereoscopic binocular. A fiber-optic light illuminated the slide from below. The image was then picked up by a Hyper HAD RGB color video camera. The video image was then captured and processed by image analysis software. For skin color analysis, a rectangular section of the caudal fin was examined on each fish for hue, intensity, and saturation values. These values were compared with *t*-tests.

Over a 2-week period in late April and early May 1997, approximately 51,000 fish in each raceway were coded-wire-tagged and adipose-fin-clipped for subsequent evaluation of survival (smolt-to-adult). The fish in each raceway received a unique batch code. These fish were reared on and then released from the hatchery in two paired releases on 7 and 9 June 1997.

It is anticipated from fall 1999 until 2003, the regional database of the Pacific States Marine Fisheries Commission (PSMFC) will be used to compare the recruitment to the fishery and relative survival to spawning of these conventionally- and seminaturally-reared fish.

On 4-6 June 1997, a subsample of 750 fish from each raceway was PIT tagged for an in-stream survival evaluation. The fish were returned to their raceway and allowed to recover from the effects of tagging. Later, they were transported in a white fiberglass tank to the upper watershed of Forks Creek (location 46° 30’ 51” N and 123° 32’ 8” W) where they were released in paired groups. Releases were made on 16 and 23 June 1997. Each paired group consisted of all the PIT tagged fish in one control and one seminatural habitat raceway. The fish were challenged to survive downstream migration to a weir located at the hatchery (46° 33’ 26” N and 123° 35’ 46” W), where they were recaptured and their PIT tag code interrogated. After all the codes were recorded, the fish were released below the weir to continue their migration to sea. Differences in the ratio in the number of fish recaptured to not recaptured were compared between the treatments with 2 × 2 contingency table analysis.

A subsample of 30 fish was removed from each raceway on 4-6 June 1997 for pathological analysis. These fish were euthanized in MS-222 and then dissected for evaluation. The condition of the spleen was observed and subjectively rated. The kidney was sampled. The posterior third of the kidney was removed and examined for the presence of *Renibacterium salmoninarum*, the causative agent of BKD, and the fluke *Nanophyetus salmincola*. Portions of the kidney were streaked on agar plates, incubated at 20° C, and examined after 24 hours for evidence of bacterial pathogens. *N. salmincola* cysts were analyzed with a *t*-test.

1998 Activities

In 1998, the number of raceways per treatment was increased from two to three. The inside walls and bottom of the control raceways were lined with a light gray fiberglass reinforced panel (2 on Kodak gray scale) to resemble the light gray color of concrete (1 to 2 on Kodak gray scale). The original resin rock pavers were replaced with new pavers made of resin that did not turn white when submerged in water. Except for these modifications the control and seminatural raceways remained the same as in 1997.

The second experiment was initiated on 27 January 1998. An equal weight of fall chinook swim-up fry (approximately 37,035 fish) was ponded into each of the experimental raceways. The fish were again reared following standard WDFW procedures. Beginning in February 1998, samples of 100 fish from each raceway were weighed and measured every month as before, and means analyzed with *t*-tests. The number of fish photographed was maintained at 60 per treatment but reduced to 20 per raceway.

Over a 2-week period in April 1998, at least 33,500 fish in each raceway were tagged and fin clipped for the evaluation of smolt-to-adult survival. These fish were then reared until 1 June 1998, when they were released from the hatchery below the Forks Creek weir. From fall 2000 to

2004, the PSMFC database will be consulted to compare the recruitment to the fishery and relative survival to spawning of fish from the two rearing treatments.

In spring 1998, the vertical position of the fish in each raceway was recorded using a grid and an underwater video system. The grid had four cells stacked vertically between the surface and bottom of the tank. Data were recorded on videotape (8 mm) for subsequent analyses.

On 1-2 June 1998, 30 fish from each raceway were sacrificed for pathological evaluation, which differed slightly from that carried out in 1997. The fish were first euthanized in MS-222. The fin condition was assessed, and fish with eroded or split fins were scored. The coelomic cavity was opened and the condition of major internal organs assessed. These results were compared with 2×2 contingency table analysis. The kidney was then sampled and evaluated as previously described for 1997.

On 1-2 June 1998, 500 fish from each raceway were PIT tagged for in-stream survival evaluations. These fish were transported and released in three paired releases at the same upper watershed location as in 1997. Paired releases were made on 10, 17, and 24 June 1998. Survival ratios were again compared with 2×2 contingency table analysis.

Results

A landslide in the Forks Creek watershed upstream of the hatchery intake occurred in early 1997. This resulted in heavy siltation during the first 6 weeks of rearing. Although the raceways were cleaned daily with a vacuum, thick sediment built up each day throughout this period. By late spring much of the sediment had been washed out, and the bottoms of the conventional raceways were clean of silt. There was no increased siltation load in 1998.

In 1997, the original pavers turned white after several days in water. This reaction appeared to be more physical than chemical. They also crumbled when taken out of the raceways. The resin rock pavers used in 1998 were a distinct improvement with the resin remaining transparent.

In 1997, it was necessary to remove the juvenile fish collection weir temporarily before PIT tag recoveries were complete due to heavy flooding. The weir was modified for the 1998 field trials and was not removed during the recovery period.

The resin rock pavers markedly reduced vacuuming time compared with that for cleaning loose gravel. Improvements in the vacuum heads and larger wheels to roll over the rocks enabled the seminatural raceways to be cleaned quickly. In general it took three passes with a seine net to catch almost every fish in seminatural raceways. It took two passes to net almost all the fish in conventional raceways.

The five fir trees suspended from a wire into each raceway were relatively easy to maintain and work around. The system enabled trees to be unclipped and rapidly removed when it was time to crowd the fish for sampling or removal. Although some branches were lost each season, the trees lasted for at least 2 years.

The camouflage net covers were also easy to work around. The covers were lifted and one side hung from a wire to provide easy access for feeding, vacuuming, or removing mortalities. For seining operations the covers were easily removed and temporarily stored next to the tank. The standing wall tanks and covers successfully eliminated all avian and mammalian predation from the study raceways, even though birds and otters were seen to prey on fish in the uncovered production raceways and ponds at Forks Creek Hatchery.

In 1997, although randomly distributed, the two fish groups differed in length and weight at ponding (Figs. 1 and 2). This difference in size had disappeared by the second sampling period. By the third sampling period, the conventionally-reared fish were significantly longer and heavier than the seminaturally-reared fish. Even after reducing the ration fed to conventionally-reared fish, they remained slightly larger than seminaturally-reared fish at the last sampling period (Figs 1 and 2).

In 1998, there was no significant difference in the length or weight of fish at either the first or second sampling periods (Figs. 3 and 4). By the third sampling period, the seminaturally-reared fish weighed significantly less, but were not shorter, than the conventionally-reared fish. In the fourth sampling period in April 1998, the seminaturally-reared fish were both significantly shorter and weighed less than their conventionally-reared counterparts. Although feed was withheld from the conventionally-reared fish to allow the seminaturally-reared fish an opportunity to catch up, conventionally-reared fish were still slightly larger than seminaturally-reared fish at the end of May 1998.

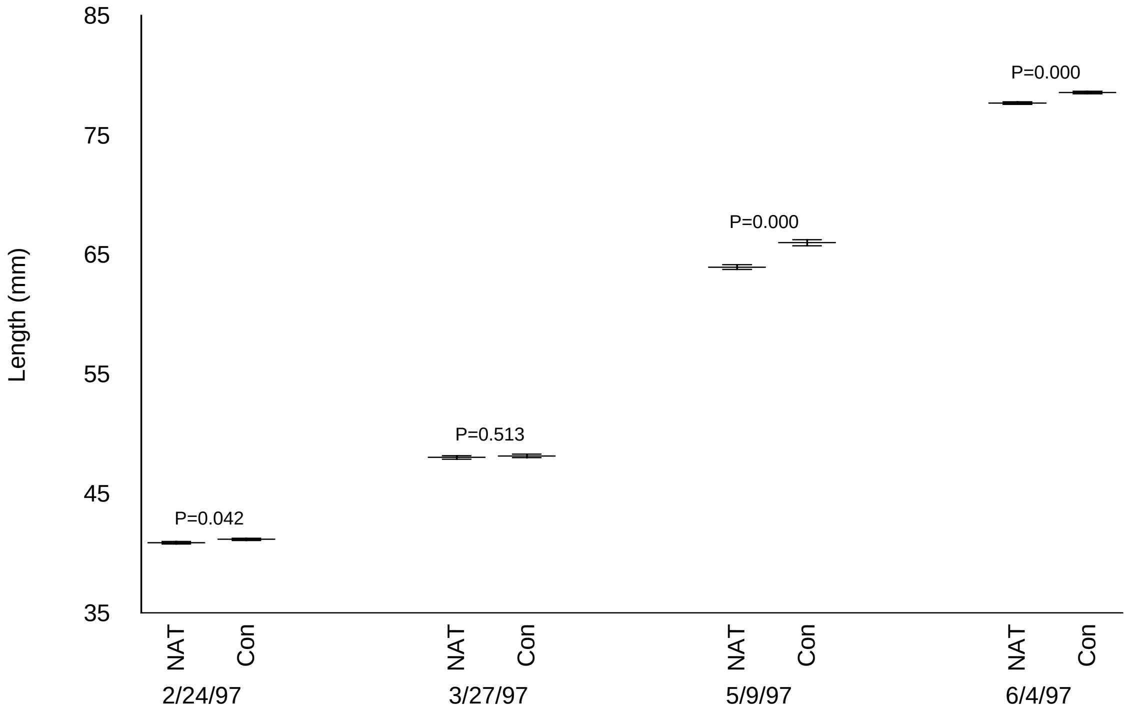

Figure 1. Mean lengths (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 200) or conventional (con, n = 200) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

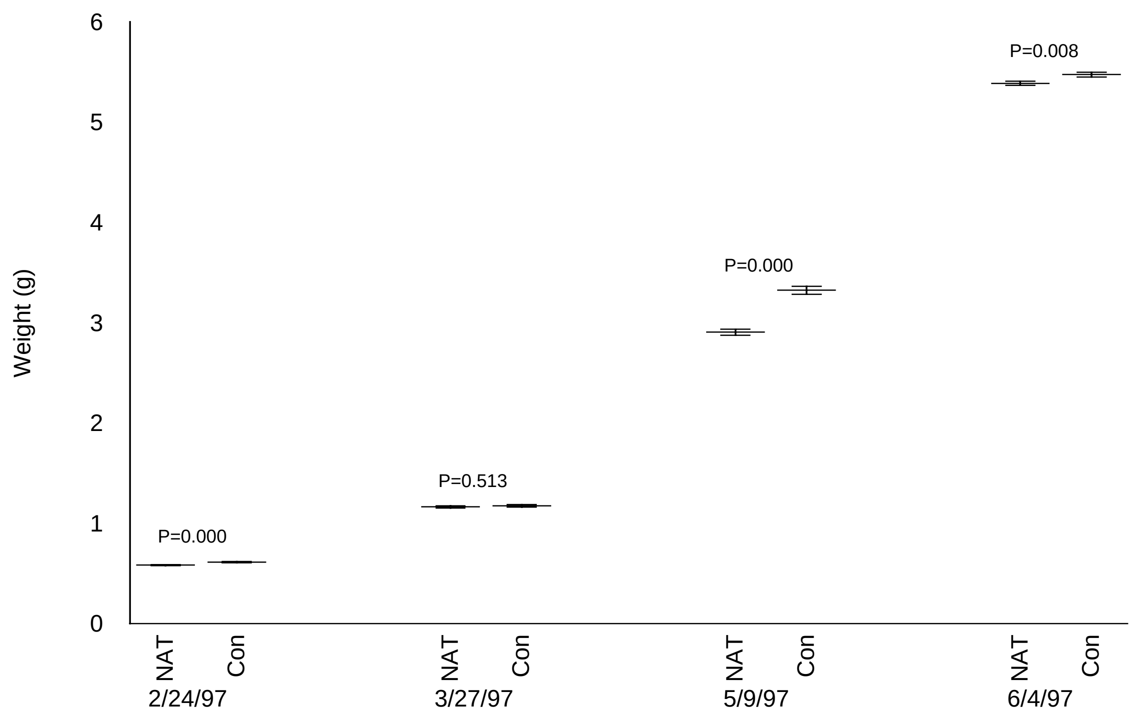

Figure 2. Mean weights (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 200) or conventional (con, n = 200) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

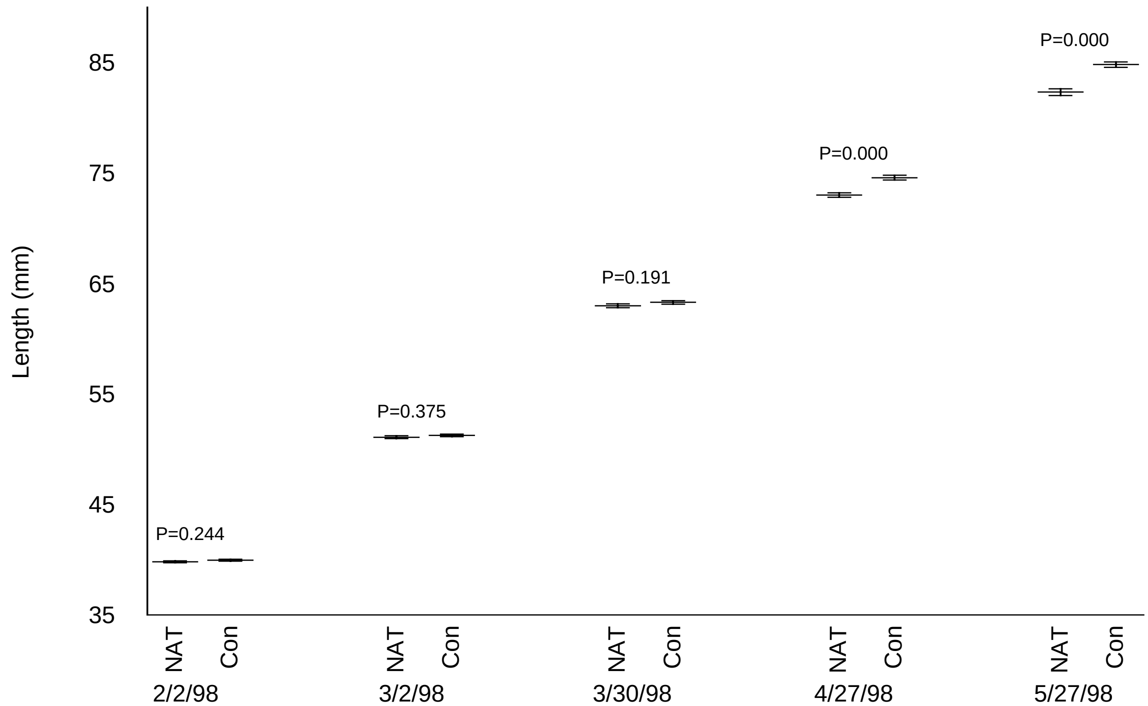

Figure 3. Mean lengths (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 300) or conventional (con, n = 300) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

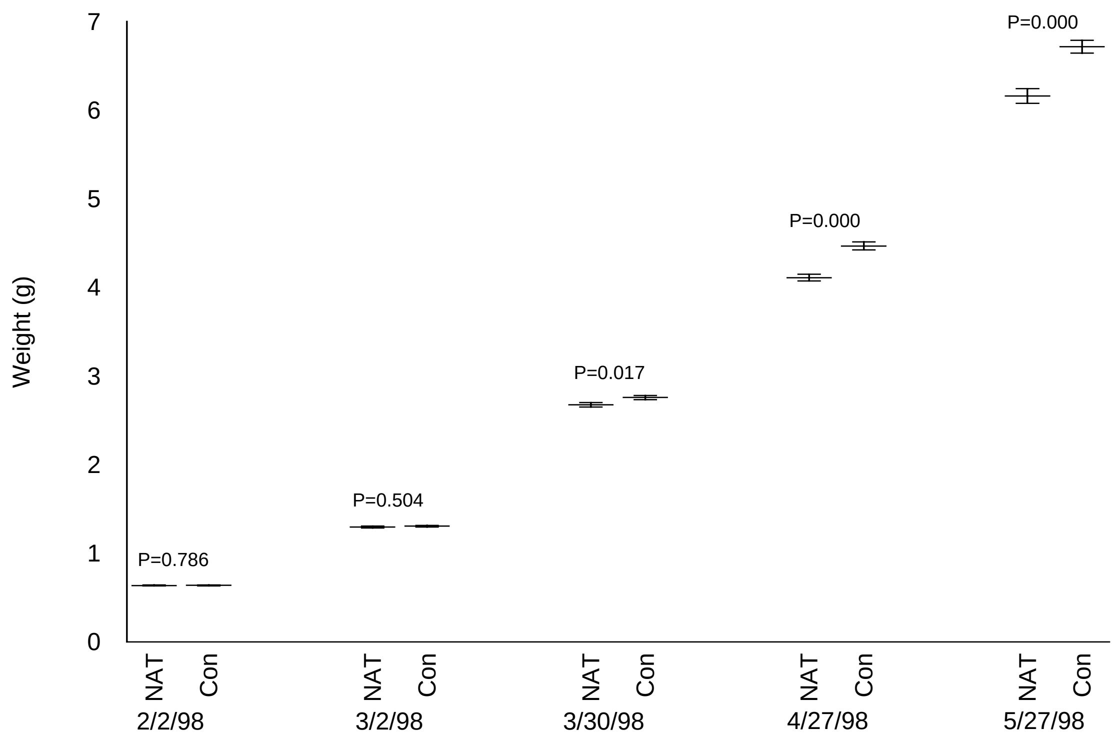

Figure 4. Mean weights (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 300) or conventional (con, n = 300) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

In 1997, fish were photographed the day they were ponded into the two rearing treatments. The skin color values for both treatments were similar at ponding (Figs. 5, 6, and 7)[2]. Statistically significant differences did not develop between the two treatments until the last sampling period in June 1997. Only two (hue and intensity) of the three color axes were significantly different from one another just prior to release. Subjectively, the seminaturally-reared fish appeared darker than the conventionally-reared fish. The caudal and pectoral fins of conventional fish were translucent, while the caudal fins of seminatural fish appeared brown. There also appeared to be much more chromatophore development in the ventral region of fish reared in seminatural rather than conventional raceways.

In 1998, photographs were taken when the fish had spent a week in their respective rearing treatments. This length of time in treatment was found to be insufficient for the fish to develop skin color differences that were statistically different (Figs. 8, 9, and 10). By March the skin color differences were statistically different, and these differences continued through the last sampling period in May 1998. Although all three color values were statistically different at intermediate sampling periods, only two of the three color axes (hue and intensity) were statistically different at the final sampling. In 1998, the subjective color differences between conventional and seminatural salmon appeared to be greater than in 1997. Again, seminaturally-reared fish had brown-tinged fins and more chromatophore development in the ventral region than conventionally-reared salmon.

The pathological data for the two rearing treatments were very similar in 1997. The kidney streaks from both rearing treatments produced no pathogen colonies on the TSA agar plates. Although *N. salmincola* cysts were observed in the kidney smears from both treatments, the average cyst counts were similar and not significantly different (Fig. 11). Enteric redmouth disease broke out in one of the control tanks in 1997, and produced some mortality. The fish in all four tanks were fed medicated (Romet) feed as soon as the outbreak was detected and diagnosed by WDFW fish health staff.

The fish were not checked for the protozoan *Ichthyobodo necator*, or given a formalin bath to prevent the high postrelease mortality this parasitic agent can cause when salmonids migrate into the marine environment.

In 1998 the health sampling program was extended to include gross assessment of fin condition and internal organs. In these observations, the percentages of fish with fin or kidney problems were similar for both rearing treatments (Figs. 12 and 13). However, abnormal spleens were observed in more conventional than seminatural fish (Fig. 14). As in 1997, none of the streaks on the TSA agar plates resulted in the growth of identifiable pathogen colonies. Enteric redmouth disease again broke out in one of the conventional raceways and all six raceways were fed medicated (Romet) feed. This immediately eliminated subsequent mortality problems

[2] The reader should be cautioned to make comparisons only between treatment values for hue, saturation, and intensity (i.e., only look at relative differences between treatments). Values should not be compared between sampling dates, as sources for film and processing, and developing times were not always consistent from one sample to the next.

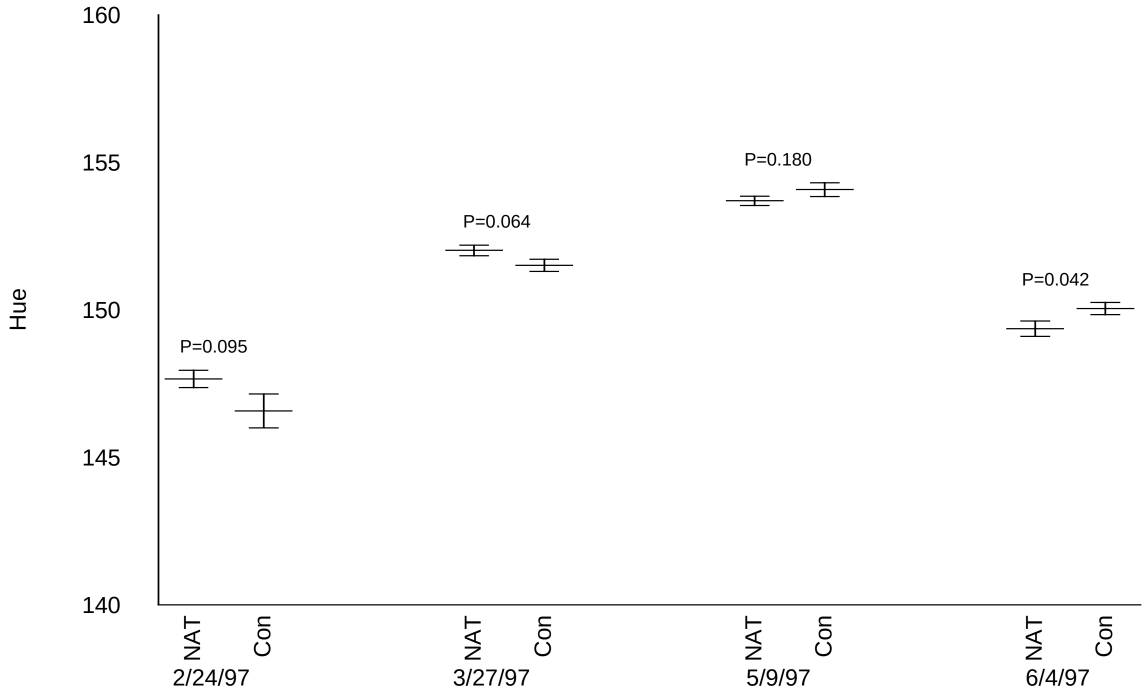

Figure 5. Mean hue values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

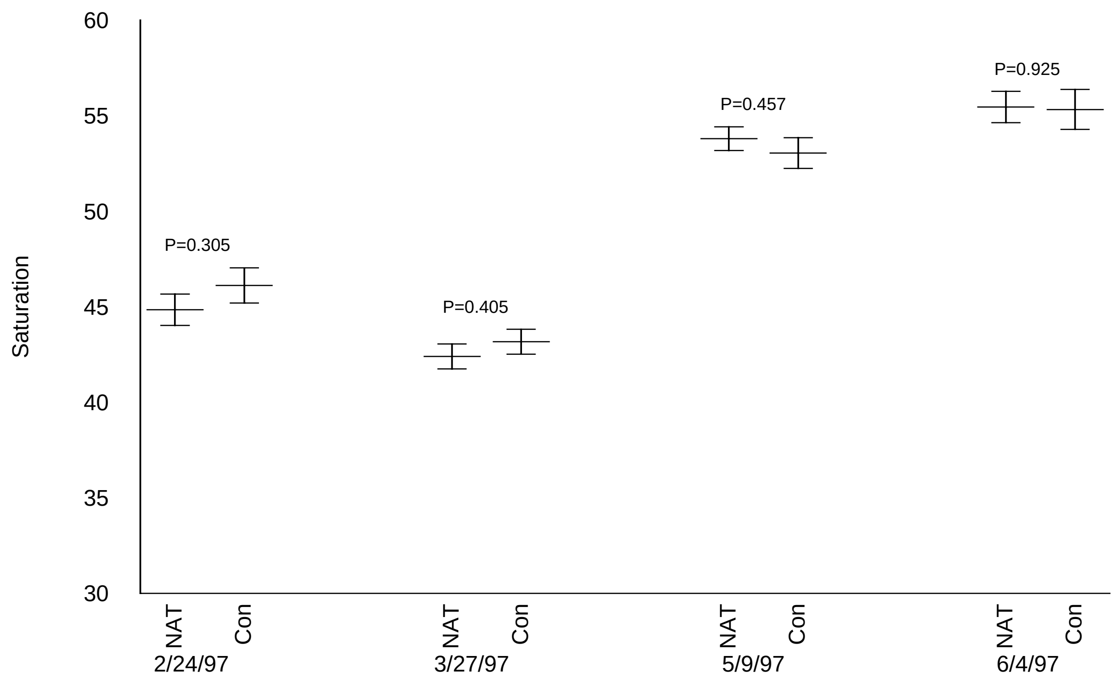

Figure 6. Mean saturation values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

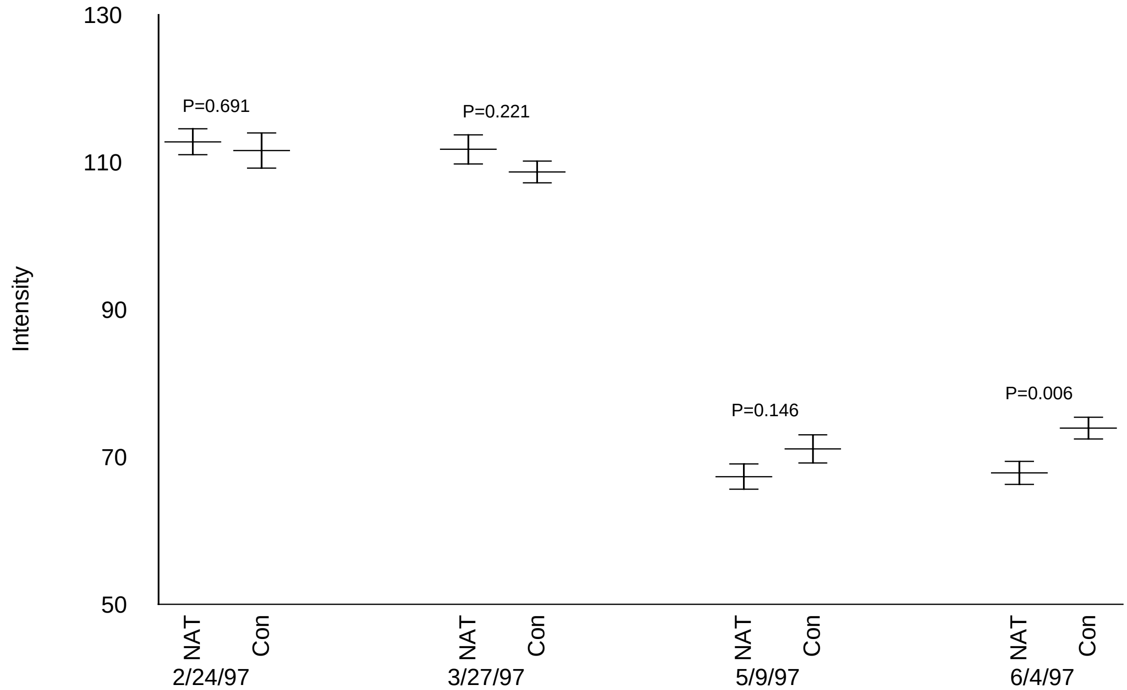

Figure 7. Mean intensity values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

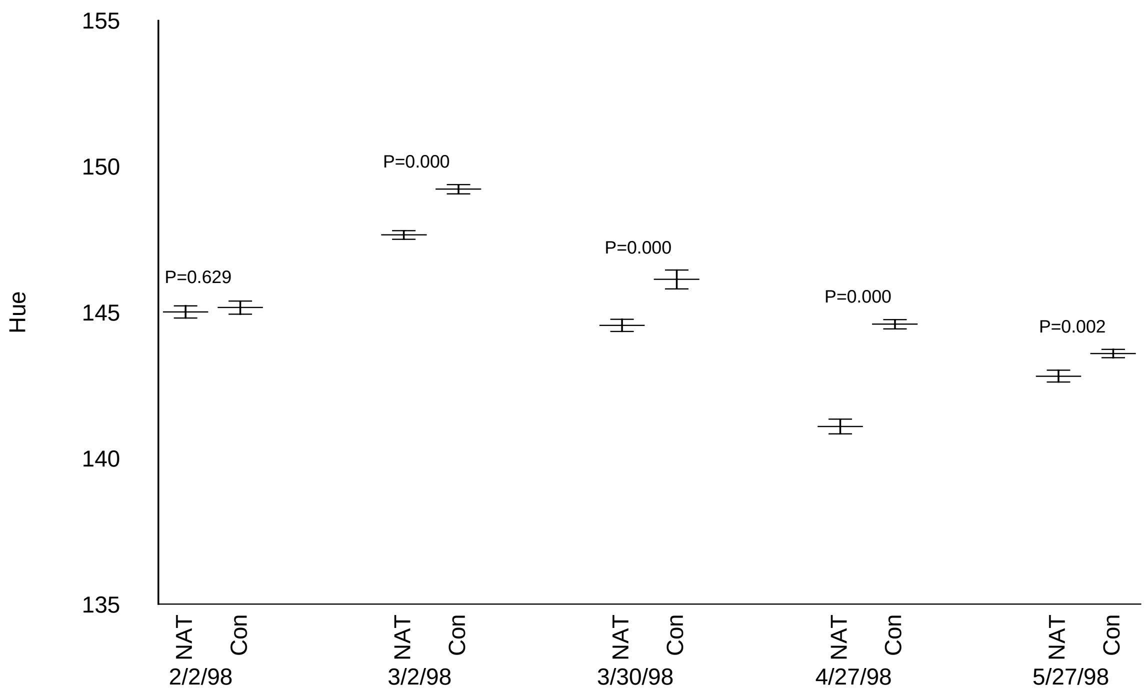

Figure 8. Mean hue values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

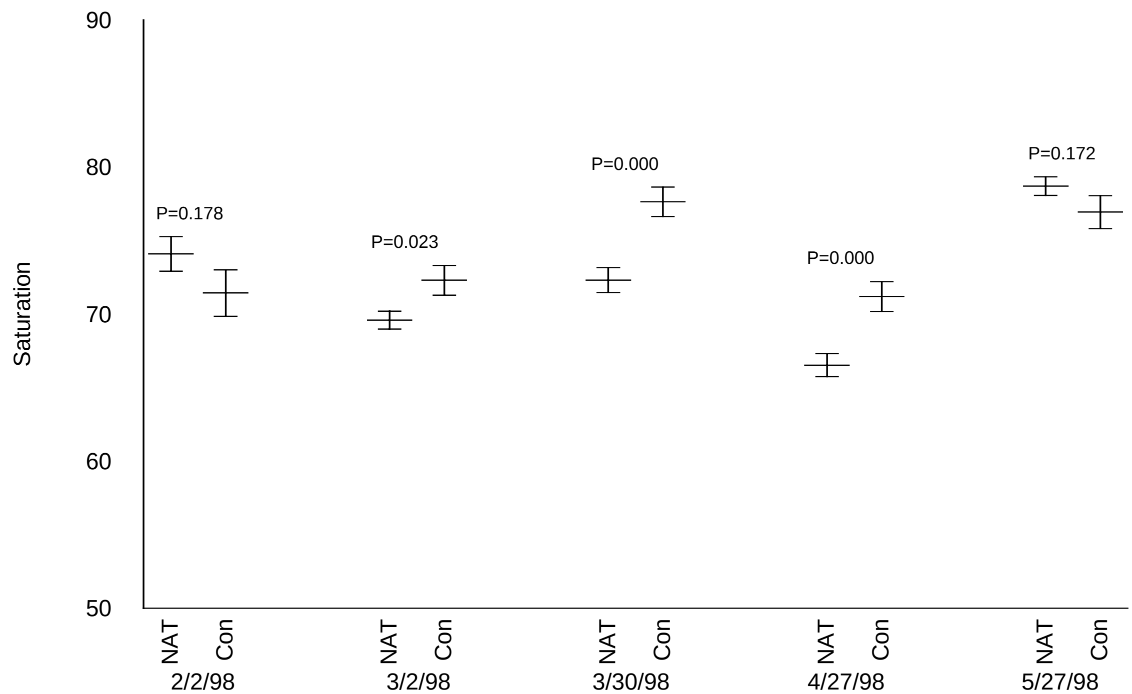

Figure 9. Mean saturation values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

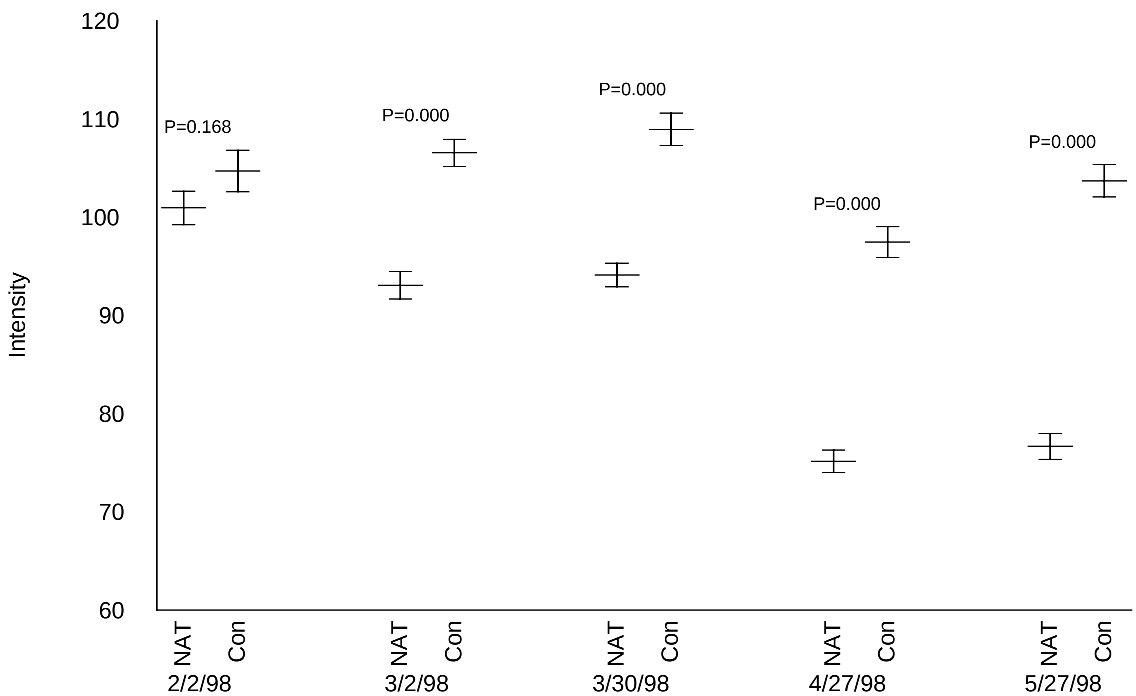

Figure 10. Mean intensity values (with standard error bars) of fall chinook salmon throughout rearing in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

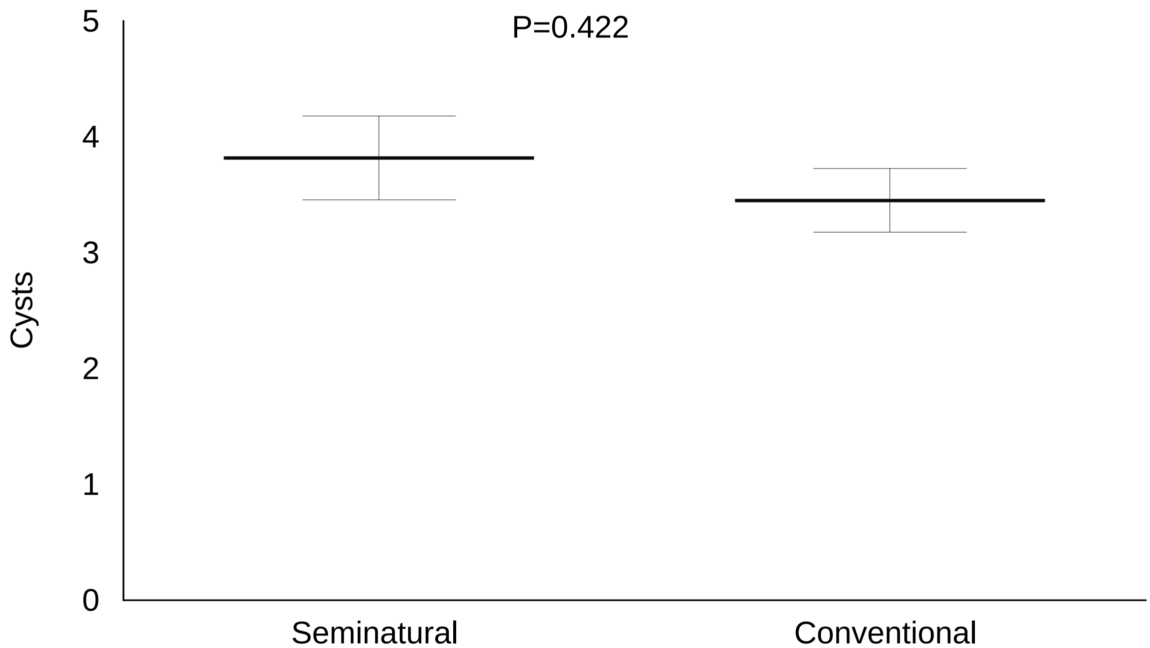

Figure 11. Mean number of *Nanophyetus salmincola* cysts found in kidney smears of fall chinook salmon reared in seminatural (n = 60) or conventional (n = 60) raceways at Forks Creek Hatchery in 1997. P values are based on *t*-tests.

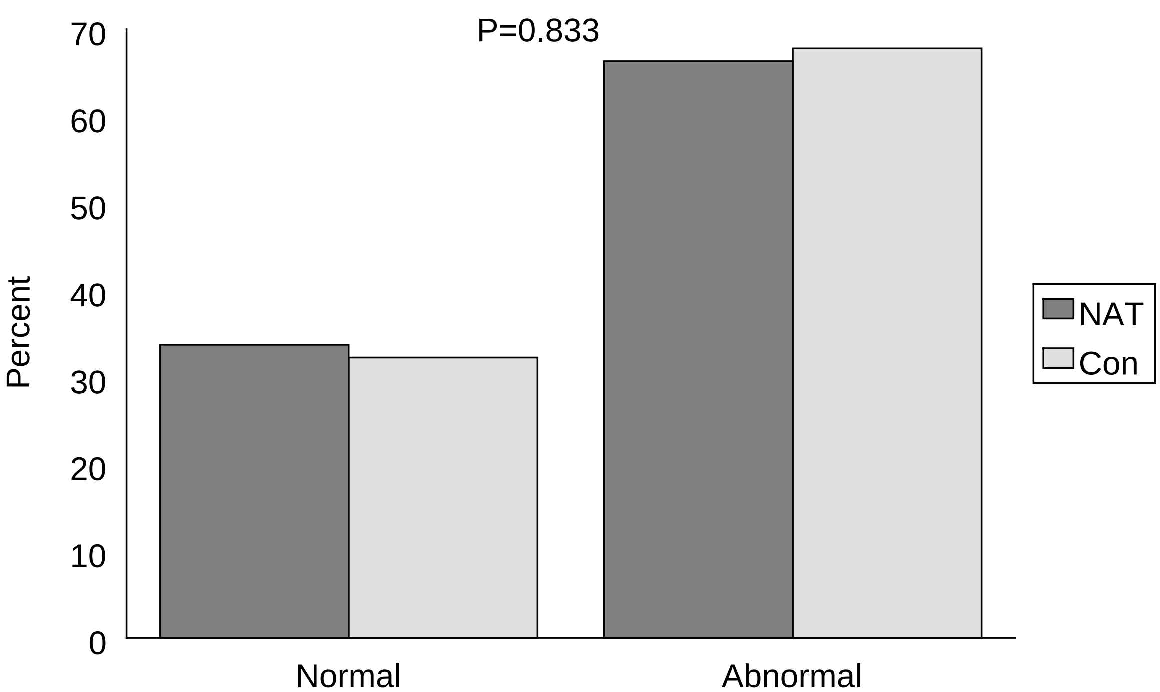

Figure 12. Percentage of fall chinook salmon with normal vs. abnormal fin conditions. Fish were reared in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

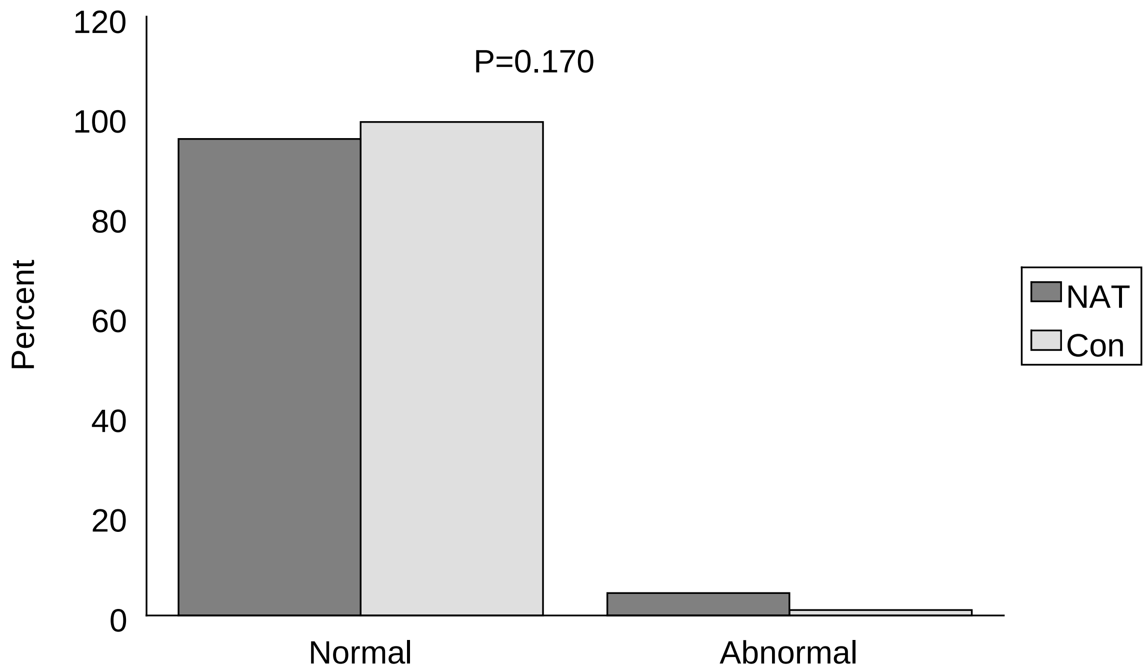

Figure 13. Percentage of fall chinook salmon with normal vs. abnormal kidneys. Fish were reared in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

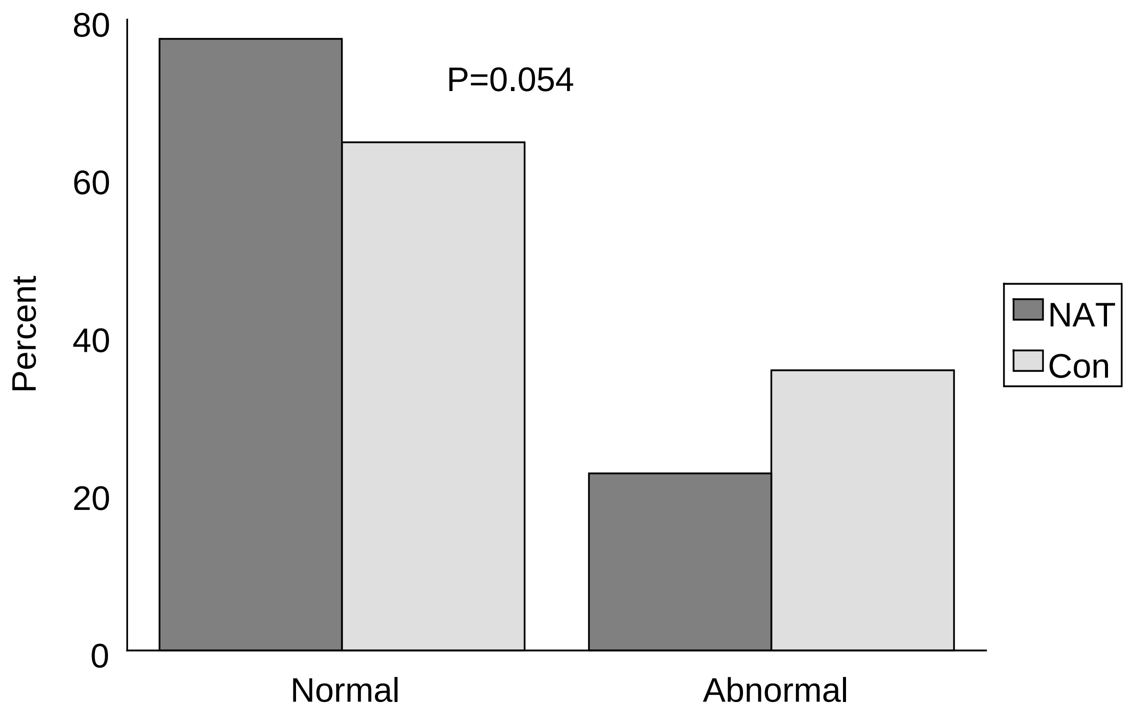

Figure 14. Percentage of fall chinook salmon with normal vs. abnormal spleens. Fish were reared in seminatural (NAT, n = 60) or conventional (con, n = 60) raceways at Forks Creek Hatchery in 1998. P values are based on *t*-tests.

developing in the diseased raceway. In 1998, the fish were checked for *I. necator* and given a formalin bath just prior to release.

The average travel time to the weir for the groups released in 1997 ranged from 1.8 to 3.9 days (Fig. 15). Rearing treatment was not a significant factor affecting the time it took fish to reach the weir, but release date was a significant factor which affected travel time. Fish in the second release generally reached the weir more rapidly than fish in the first release. There was no significant interaction between treatment and release date in the 1997 experiment.

In 1998 fish took longer time to reach the weir, with the average travel time for the groups ranging from 2.96 to 6.49 days (Fig. 16). However, as in the previous year, there was no significant effect of rearing treatment on travel time, but there was again a statistically significant effect of release date on travel time. Fish in the first release took the longest time to reach the weir, fish in the second release took a slightly shorter time, and the fish in the third release reached the weir in the least time. Again there was no statistically significant interaction between rearing treatment and release date.

The majority of the fish released in both 1997 and 1998 survived downstream migration to the weir at Forks Creek Hatchery (Figs. 17 and 18). In both 1997 releases, slightly more seminaturally-reared than conventionally-reared chinook salmon were recovered at the weir, but the difference was not statistically significant. In two of the three 1998 releases, significantly more seminatural than conventional fish were recovered at the weir. The other 1998 release also had more seminatural than conventional fish recovered, but the difference was not statistically significant.

In 1997, more than 45,000 coded wire tagged fish were released from each raceway (Table 1) for a total of more than 95,000 fish released per treatment. In 1998, more than 32,000 fish were released from each raceway, for a total of more than 96,000 fish being released per treatment.

Table 1. Coded wire tagged releases of fall chinook salmon from Forks Creek Hatchery NATURES project, 1997-1998.

	Raceway 21	Raceway 22	Raceway 23	Raceway 24	Raceway 25	Raceway 26
Treatment	control	seminatural	control	seminatural	control	seminatural
1997						
CWT + Ad clip	44,172	46,258	47,589	45,368	N/A	N/A
CWT only	2,068	2,235	1,405	1,773	N/A	N/A
1998						
CWT + Ad clip	33,154	34,008	33,267	32,507	32,606	33,994
CWT only	194	0	67	66	97	34

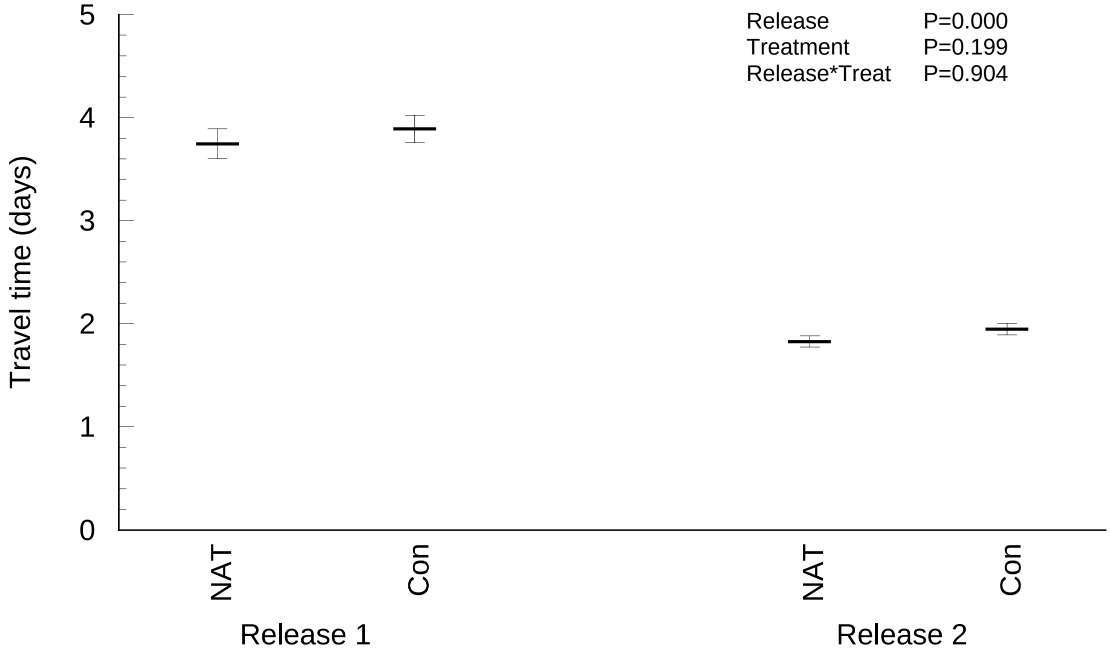

Figure 15. Mean travel time (with standard error bars) for outmigrating fall chinook salmon reared in seminatural (NAT, n = 1,042) or conventional (con, n = 1,036) raceways at Forks Creek Hatchery in 1997. Travel time is measured as days from release above hatchery to recapture at a weir downstream. P values are based on two-factor ANOVA.

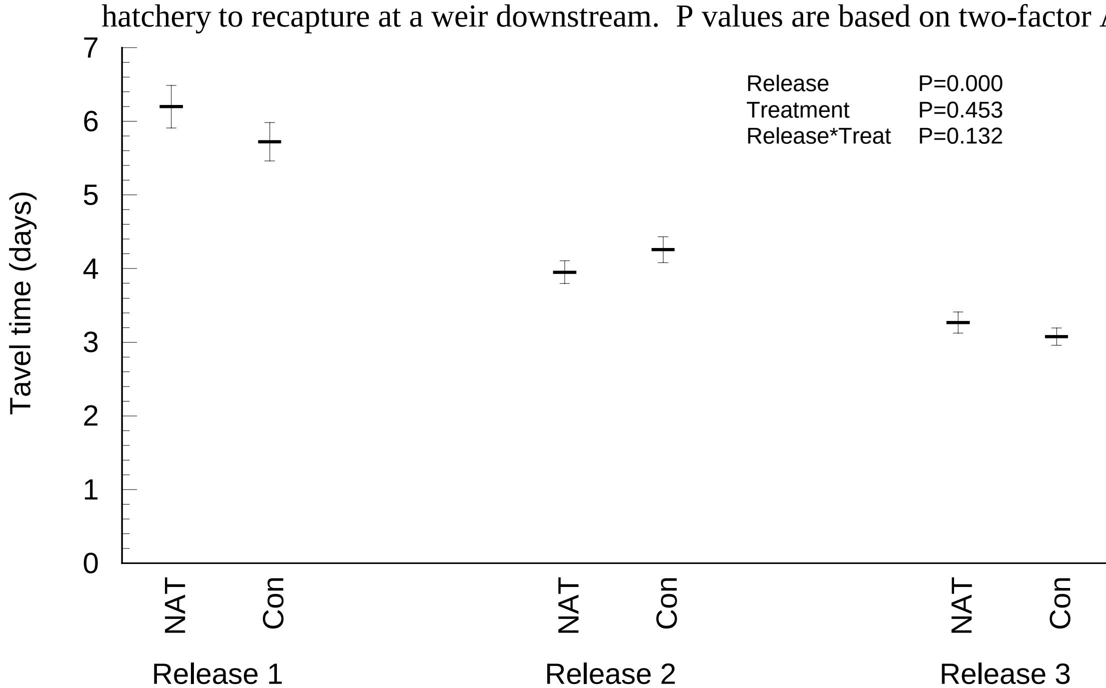

Figure 16. Mean travel time (with standard error bars) for outmigrating fall chinook salmon reared in seminatural (NAT, n = 988) or conventional (con, n = 890) raceways at Forks Creek Hatchery in 1998. Travel time is measured as days from release above hatchery to recapture at a weir downstream. P values are based on two-factor ANOVA.

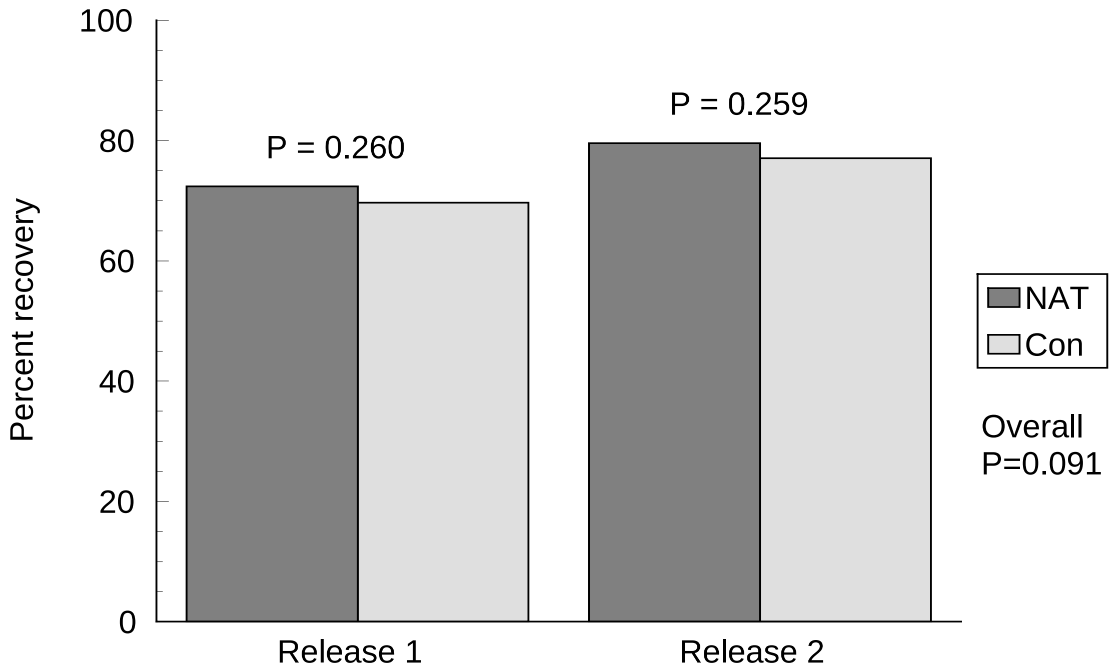

Figure 17. Percent of fall chinook salmon recovered in smolt-to-smolt survival evaluations. Fish were reared in seminatural (NAT, n = 1,042) or conventional (con, n = 1,036) raceways at Forks Creek Hatchery in 1997. P values are based on chi-square analysis.

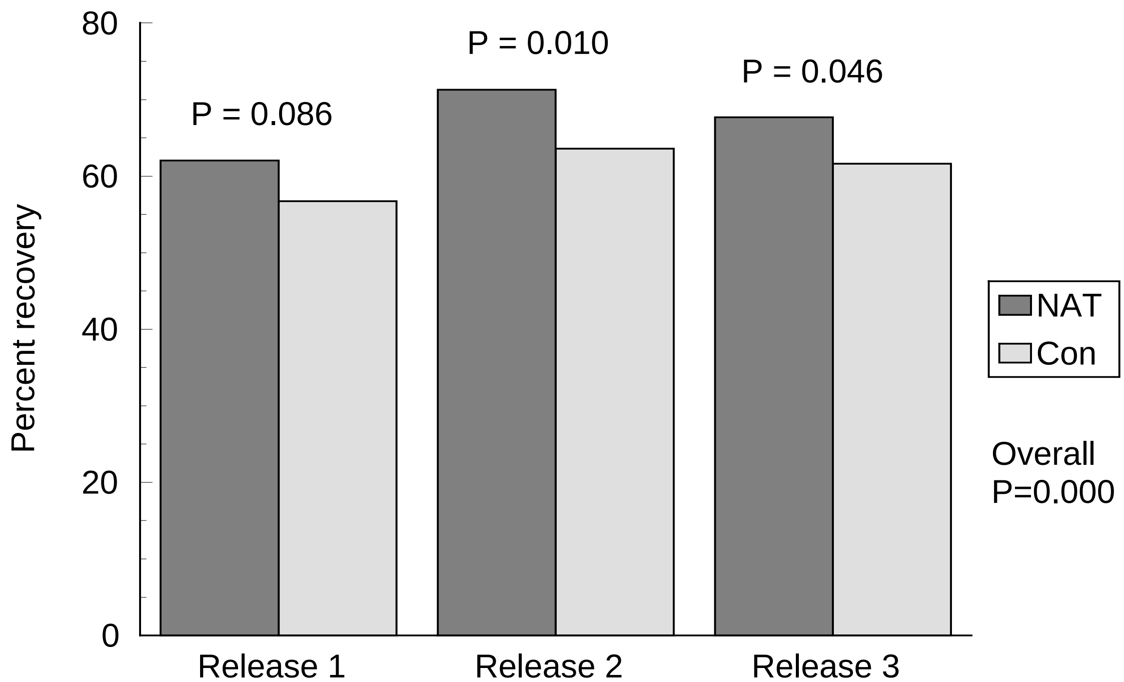

Figure 18. Percent of fall chinook salmon recovered in smolt-to-smolt survival evaluations. Fish were reared in seminatural (NAT, n = 1,001) or conventional (con, n = 899) raceways at Forks Creek Hatchery in 1998. P values are based on chi-square analysis.

Discussion

The recovery trend in all five paired releases supports the work of previous studies (Maynard et al. 1996 b, c, d) that rearing fish in a seminatural raceway habitat tends to improve in-stream survival. The skin color of the fish reared in the two treatments was different, reinforcing the earlier hypothesis that the development of proper camouflage coloration for the postrelease environment is responsible for the increased in-stream survival (Maynard et al. 1996c, 1996d). In nature, this attribute would benefit the fish not only as they move down the river, but also as they reside for several weeks over the dark brown substrate of the Willapa estuary.

The small differences in in-stream survival in 1997, which were not statistically different, may have been the result of poorly chosen or unusual experimental criteria that year. First, the walls in the control raceway were colored dark gray, which would promote the development of darker skin coloration in both treatments. Second, the continuous sedimentation in the conventional raceways that occurred during the first 2 months of that year produced a skin coloration in both treatments which blended with the natural brown background of the Willapa River. Finally, the resin of the original pavers discolored, perhaps resulting in lightened skin coloration of the fish reared in seminatural raceway habitat that year.

In 1998, the differences in hue, saturation, and intensity values between the two treatments were more consistent than in 1997, and the relative in-stream survival advantage for seminaturally-reared fish was greater. These observations, coupled with the increased in-stream survival in 1998, suggest that lightening the color of the walls of the control raceways, and replacing the pavers, were important improvements. The reduced sedimentation in 1998 was probably another critical factor increasing the relative survival differences.

In the Forks Creek experiment, the loose gravel substrate used in three earlier seminatural raceway habitat studies (Maynard et al. 1996a, b, d) was replaced with resin rock pavers to reduce the labor involved in management. Although not as easy to work as the conventional raceways, the pavers were much easier to vacuum than the loose gravel. Once modified, the new pavers provided similar color development and survival benefits previously found with loose gravel.

The modified pavers also provided a similar or even more hygienic rearing environment than conventional rearing habitat, as disease broke out more in the conventional tanks rather than in the seminatural tanks. In the 1992 experiment (Maynard et al. 1996d), this increased hygiene was attributed to the undergravel filters removing decaying particulates (food and feces) from the water column. Possibly, as food falls in the interstitial spaces between the pavers, they too keep it from being put back into the water column. At this point in time, the main improvement to the pavers would be to make them even easier to vacuum by using smaller rocks, similar in size to those used for exposed aggregate. This smaller rock would enable the wheels of the vacuum to move easily, and bring the vacuum head closer to the substrate. On the other hand, fewer but larger rocks might be easier to vacuum and therefore some further designs still need to be engineered and tested.

The type of habitat in which fish are reared does not appear to affect their travel time downstream. However, in both 1997 and 1998, the release time had a significant effect on travel time. The earlier the fish were released, the longer their mean travel time. It is possible that later released fish were more advanced smolts with a more urgent need to migrate downstream. It is also possible that the stacking of several releases confounds travel time results. In every release in 1997 and 1998, a very large percentage of fish moved immediately downstream, and was recovered at the weir within 3-5 days of release. After this, the remaining fish trickle through in smaller steady quantities. When a second group is released “on top” of the previous release group, a secondary spike of recoveries of the first release corresponds with this initial spike of recoveries from the second release group. These fish flushed out from the first release by the second release might consist of fish which would ordinarily reside in the creek longer. In either case the flushed fish in the earlier release group lengthen the group’s mean travel time, while the greater number of fish in the later release group that cannot take up residence decrease mean travel time. Fish were not pushed out of the creek more rapidly in later releases by floods or the current, as water flow in the creek decreased over time. Thus later releases may have shorter travel times because:

(i) they are better developed smolts,

(ii) mean times are lowered by the displacement of earlier residents and later released fish being less likely to obtain resident sites, or

(iii) other factors that may have produced this travel time pattern.

At this point the authors believe it is more probable that the second factor (ii) is responsible for the decreased travel time observed for the later releases in 1997 and 1998.

The preliminary results indicate that seminatural raceway habitat rearing improves cryptic coloration and in-stream survival in production size vessels and at production densities. The majority of the study fish are now at sea. As these fish return over the next several years, they should provide answers to the question of whether or not seminatural rearing also improves smolt-to-adult survival.

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