

**INCREASE POSTRELEASE SURVIVAL BY REARING COHO SALMON WITH  
NATURES SEMINATURAL RACEWAY HABITAT**

**Progress Report  
For Period**

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by

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## ABSTRACT

In 2000, National Marine Fisheries Service initiated a study at three Washington Department of Fish and Wildlife Puget Sound hatcheries to test the concept of modifying raceways by installing gravel-paver substrate, fir tree structure, and camouflage net cover. Each hatchery has one modified (experimental) and one unmodified raceway. Fish are then reared in this more natural environment for at least the last two months of their fish culture phase. This year, there were no significant differences in size or health between the treatments at time of release. However, similar to previous NATURES studies, the seminaturally reared fish developed a more natural camouflage coloration as measured by hue, saturation, and intensity. This increased crypticity should theoretically increase survival by decreasing vulnerability to visually hunting predators (fish, birds, mammals). Fish culturists may be able to use NATURES seminatural raceway habitat rearing to increase the number of coho salmon (*Oncorhynchus kisutch*) recruiting to the fishery. In future years, the recovery of coded-wire tag data from the fishery and returns to the hatchery will be used to compare the effect of the two rearing strategies on coho salmon smolt-to-adult survival.

## EXECUTIVE SUMMARY

New salmon culture techniques must be developed if the survival of hatchery fish recruiting to the fishery or spawning population is to be increased. Low survival rates are unacceptable as public hatcheries produce up to 80% of the salmon available for harvest and are often the only broodstock source available for restoring depleted natural runs. In addition, low survival rates force hatcheries to rear and release more fish per recruit to the fishery, which both reduces economic efficiency and increases the risk of negative interactions with ESA listed stocks. Fortunately, there appears to be scope for improvement as the smolt-to-adult survival of hatchery fish is often much lower than that of wild-reared salmon.

Seminatural raceway habitat rearing is the most successful component of the Natural Rearing Enhancement System (NATURES) jointly developed by the National Marine Fisheries Service (NMFS), the Washington Department of Fish and Wildlife, and the Bonneville Power Administration. Seminatural raceway habitat is composed of gravel substrates, inwater structure, and overhead cover that is installed in raceways to produce a rearing environment resembling the stream habitats utilized by juvenile chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon. In previous NATURES studies conducted by NMFS, rearing hatchery chinook salmon in seminatural raceway habitat has improved their instream postrelease survival up to 50%. The present study was initiated to determine if seminatural raceway habitat rearing also produces similar increases in postrelease survival for hatchery coho salmon.

The study's experimental design tests the hypothesis that rearing coho salmon in seminatural raceway habitat increases their smolt-to-adult survival. The approach is to rear coho salmon in standard-sized control and seminatural raceways for at least the last two months of their culture, release them into the wild, and then compare their smolt-to-adult survival. This study uses a paired approach, with one control and one experimental raceway at each of initially three different Puget Sound hatcheries.

The study has successfully attained all its first year objectives. Experimental raceway habitats were developed, successfully installed, and operated at the production scale facilities. All the fish were coded-wire tagged and all inculture growth, color development, and fish health data have been collected. There was no difference in fish size nor health status between test and control raceways. However, at release, measurable cryptic camouflage body coloration differences had developed between the fish in the two rearing treatments at all three experimental facilities.

These first year findings indicate that seminatural raceway habitat can be operated at production scale facilities and produce camouflage coloration changes in coho salmon that seem to improve the instream postrelease survival of chinook salmon. It is anticipated that these color differences will also increase hatchery coho salmon smolt-to-adult survival. Fishery managers can use this increased postrelease survival to improve hatchery efficiency, increase harvest, speed the rebuilding of self-sustaining natural runs, or simply reduce the ecological impact of hatchery fish on ESA listed stocks, while maintaining recruitment to the fishery at current levels.

## PURPOSE

New salmon culture techniques must be developed if the survival of hatchery coho salmon (*Oncorhynchus kisutch*) recruiting to the fishery or spawning population is to be increased above the 10-20% experienced by those released from good quality Puget Sound hatcheries. Low rates of survival are unacceptable as public hatcheries produce up to 80% of the salmon available for harvest and are often the only broodstock source available for restoring depleted natural runs. In addition, low survival rates force hatcheries to release more smolts that could negatively interact with ESA listed stocks than would be necessary with higher survival rates. Fortunately, there appears to be scope for improvement as the smolt-to-adult survival of hatchery fish is often much lower than that of wild-reared salmon. It appears that salmonids produced with traditional fish culture techniques lack many of the behavioral, physiological, and morphological characteristics needed to survive in the wild immediately after release (see the review by Maynard et al. 1995). It may be possible to promote the expression of these wild characteristics by rearing salmonids in a hatchery environment that resembles natural stream and river habitats. This is the paradigm behind the NATURES seminatural raceway habitat concept.

In partnership with the Washington Department of Fish and Wildlife (WDFW), for a number of years the National Marine Fisheries Service (NMFS) has been developing a Natural Rearing Enhancement System (NATURES) consisting of seminatural raceway habitat, live food diets, exercise systems, predator avoidance training, underwater feed delivery systems, and oxygen supplementation, (Maynard et al. 1995, 1996 a, b, c, d). The most successful component of NATURES rearing has been the development of seminatural raceway habitat. Seminatural raceway habitat is composed of gravel substrates, inwater structure, and overhead cover that is installed in raceways to produce a rearing environment that resembles the stream and river habitats utilized by juvenile chinook and coho salmon. This differs from the environmental enrichment research previously conducted with coho salmon, which included structure and cover but lacked substrate (Vander Haegen and Appleby 1998). Studies conducted with chinook salmon (*O. tshawytscha*) have shown that seminatural raceway habitat rearing can improve instream postrelease survival up to 50% (Maynard et al. 1996b). The following study was initiated to determine if seminatural raceway habitat rearing produces similar increases in coho salmon postrelease survival.

The study's experimental design tests the hypothesis that rearing coho salmon in seminatural raceway habitat increases their smolt-to-adult survival. The experimental approach is to rear coho salmon in standard-sized control and seminatural raceways for at least the last two months of their culture, release them into the wild, and then compare their smolt-to-adult survival. A relatively unique attribute of the study is that it is being conducted with paired raceways at three Puget Sound hatcheries spread over a large geographic range. This approach enables the findings to be extrapolated throughout western Washington and removes the specter of the findings being unique to a single facility.

## **Project Objectives**

1. Starting with designs used in previous experiments, construct and install NATURES rearing habitat that is compatible with daily activities at a salmon hatchery.
2. Compare color development of fish reared using conventional techniques to the color development of fish reared using NATURES habitat.
3. Compare growth of fish reared using conventional methods to fish reared using NATURES habitat.
4. Compare the smolt-to-adult survival of fish reared using conventional methods to fish reared using NATURES habitat.

## **APPROACH**

### **Study Sites and Experimental Design**

The 2000-2001 research was conducted at WDFW Kendall Creek Hatchery near Kendall (WA), Soos Creek Hatchery near Auburn (WA), and Minter Creek Hatchery near Purdy (WA). The ponds at Kendall and Soos Creek Hatcheries are standard raceways that are about 3 m wide by 30.5 m long, while Minter Creek has much larger raceways that are about 6.1 m wide and 36.6 m long. At both Kendall Creek Hatchery and Soos Creek Hatchery the fish are reared in first-pass water. At Minter Creek Hatchery, the fish are reared on unprocessed second-pass water. There is also a markedly different distance the fish must migrate downstream to reach the estuary, with Minter Creek Hatchery being adjacent to the estuary, while both Kendall and Soos Creek Hatcheries are many kilometers inland. Kendall Creek fish migrate down the Nooksack River through a mostly rural corridor, while Soos Creek Hatchery fish must migrate downstream through a primarily suburban-urban corridor. The two additional hatcheries (WDFW Issaquah and Sol Duc) that will be added to the experiment in 2002 will add even more site differences, with Sol Duc using operational Burrow's ponds and fish migrating from Issaquah passing through Lake Washington.

At each facility, two similar raceways were selected for the experiment. One of these serves as an unmodified control, while the second is fitted with seminatural raceway habitat. This is an acclimation study, in which fish are conventionally reared until their second year of life when the experimental fish are introduced into the raceways with seminatural raceway habitat for final rearing. A control and experimental group of coho salmon will be reared at each of the five facilities through 2004 to provide a total of 18 paired releases for experimental evaluation of smolt-to-adult survival.

It was necessary to refine previous seminatural raceway habitat components for installation in the production raceways at each WDFW facility prior to initiating the experiment. The first step was to develop a concrete gravel paver that was lower in cost, more durable, and easier to install than the resin-rock pavers used in the earlier Forks Creek study with chinook salmon (Maynard et al. in prep.). The new paver was fabricated by first covering the bottom of a 46 % 46-cm mold that is 5 cm deep with

2.2-cm gravel similar in color to the stream and river bottoms where the fish are released. Concrete (colored to match river sand) was then poured in the mold and allowed to cure. After curing, the pavers were removed from the mold and stored on pallets until installation. The pavers were installed by simply laying them down side by side until the entire raceway bottom was covered. Paver weight alone is sufficient to hold them in place. A brick saw is required to cut pavers into smaller pieces to fill in gaps along the raceway wall edge. Using this technique, pavers were successfully installed at all three hatchery sites in the winter of 2000-2001. Procurement is now underway for pavers for the two additional hatchery sites that will come on-line in fall 2001.

Camouflage net covers were developed, constructed, and installed at all three hatcheries. As in previous seminatural raceway habitat studies, military camouflage netting is suspended within 90 cm of the water surface. The netting is suspended from aluminum frames and covers from 50 to 80% of the raceway surface. Each hatchery utilized a different model of cover for the 2001 rearing year. Temporary covers were constructed at Kendall Creek Hatchery until covers like those installed at Soos Creek Hatchery could be manufactured next year. A series of ten 3.9 % 2.6-m covers were made of 2.5-cm box aluminum, covered with camouflage netting, and suspended from an aluminum post (5 % 5 cm, 0.6 cm thick) and beam (2.5 % 5 cm, 0.3cm thick) structure. The Soos Creek Hatchery design is a rectangular 1.67 % 3.1-m frame constructed from 2.5-cm square aluminum tube. The frame is attached by pins to a galvanized piece of 10 % 10-cm angle iron to form a hinge. The angle iron is then bolted to the concrete wall on one side of the raceway. When lowered, the opposing frame end is supported by a 2.5 % 2.5-cm piece of angle-aluminum attached to the other raceway side. Two hydraulic lift struts are attached to the cover frame to reduce the effort required to lift the frame to the fully open position. This design enables fish culturists to quickly and easily open the covers when they need to feed fish or vacuum the raceways. The Minter Creek Hatchery covers are built from 5-cm square aluminum tube and are 6.4 % 6.4-m squares that span the raceway. Each aluminum frame is supported by wheels that rest on a track running the length of the raceway. Stainless steel cable spans the frame diagonally for extra support, and the camouflage net was initially draped over these cables and fastened to the cover frame. However, after the covers failed due to snow load the camouflage net was suspended below the frame on wire ties that should break away when loaded with snow. There are three covers per raceway and each cover can be moved back and forth on the rail as necessary for raceway vacuuming.

The instream structure used in this experiment is similar to that used in previous NATURES research. At all three hatcheries structure has been installed by suspending a stainless steel cable the length of the raceway, and hanging denuded fir trees weighted with rebar from that cable. Trees are attached to the cable with carabiner-type clips and can be readily removed for cleaning or replacement. This structure differed from that used in previous WDFW research, where plastic containers were sunk to the raceway bottom with sandbags (Vander Haegen and Appleby 1998).

In 2001, the fish were transferred into the NATURES raceways as soon as modifications were completed. Both control and experimental fish were maintained in similar conditions until this time. After being placed into the experiment, the fish were reared similarly except for the presence or absence of seminatural raceway habitat.

## **Experimental Rearing**

The control and experimental raceways at Kendall Creek Hatchery each received approximately 51,000 BY99 coho salmon on 11 January 2001. Of the fish in the control raceway, 7,656 were coded-wire tagged and adipose fin-clipped and an additional 7,656 were coded-wire tagged alone. The seminatural raceway had 7,656 coded-wire tagged and adipose fin-clipped fish, as well as 7,658 coded-wire tagged only fish. These fish were tagged on 28 June 2000, prior to initiation of experimental rearing.

Soos Creek Hatchery was the second facility to begin NATURES rearing in 2001. On 25 January, approximately 55,000 BY99 coho salmon were transferred into the seminatural raceway at Soos Creek Hatchery. In both the control and experimental raceways, 5,100 fish were coded-wire tagged and adipose fin-clipped, with an additional 5,100 fish coded-wire tagged only. All tagging was completed prior to initiation of the experiment.

In 2001, Minter Creek Hatchery was the last facility to initiate experimental rearing. Coded-wire tagging took place prior to experimental rearing, on 21 and 22 June 2000, when 10,040 of the coho designated as controls received coded-wire tags and adipose fin clips, and 10,124 of those designated to be NATURES fish received coded-wire tags and adipose fin clips. The control raceway at Minter Creek Hatchery initially contained 298,200 BY99 coho salmon, and 300,075 coho were transferred into the seminatural raceway on 28 February 2001.

## **Growth, Coloration, and Health**

At all experimental sites a sample of 100 fish was removed monthly 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 8008S 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 tricaine methane-sulfonate (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 and placed on a PVC plate (with the center drilled out) attached to the stage of a stereoscopic binocular microscope. A fiber-optic light illuminated the slide from below. The image was then recorded by a Hyper HAD RGB color video camera, 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.

Near the time of release, 30 fish were sacrificed from each raceway for fish health examinations. In 2001, these examinations occurred on 10 May at Kendall Creek Hatchery, on 27 April at Soos Creek Hatchery (on a subsample of fish held back from the

main release), and on 4 May at Minter Creek Hatchery. In each examination, the fish were first euthanized in MS 222 and then the external condition of the fish assessed using the Goede Index (Adams et al. 1993). Blood samples were then drawn to assess each fish's hematocrit, leukocrit, and serum protein profile. The coelomic cavity was then opened and the condition of major internal organs assessed using the Goede Index. A kidney smear was then plated on TSA agar to assay pathogen presence. Morphological and pathogen presence data were compared with 2 % 2 contingency table analysis. Blood parameters were arcsine transformed (hematocrit only) and compared with *t*-tests.

### **Smolt-to-Adult Survival Evaluation**

Fish were released on site at each of the facilities following standard WDFW protocols. The fish at Kendall Creek Hatchery were released on 16 May 2001 following 18 weeks of experimental rearing. On 19 April 2001, following 8 weeks of experimental rearing, fish were released from Soos Creek Hatchery. At Minter Creek Hatchery fish were volitionally released overnight on both 15 and 16 May 2001 and all remaining fish were forcefully released on 17 May 2001 after 11 weeks of experimental rearing.

### **Project Management**

This project was collaboratively managed by NMFS and WDFW. Coded-wire tagging and fish rearing was primarily performed by WDFW. Seminatural raceway habitat development and installation was primarily performed by NMFS. Data collection and analysis were conducted collaboratively by the two agencies.

## **FINDINGS**

### **Growth, Coloration, and Health**

Most of the growth, coloration, and fish health samples for this first rearing year have now been processed and statistically analyzed. From tagging until they were placed into the experimental raceways the fish were reared in separate, but similar, vessels. The staff at each hatchery was advised to rear the fish in an identical fashion during this time period. None the less, the lag between tagging and placement into experimental raceway habitat provided an opportunity for differences to develop between the paired groups prior to experimentation. At all three facilities, sampling did not begin until at least 1 week after fish were ponded into the experimental raceways.

At all three hatcheries, some size differences already existed between the paired rearing treatments at first sampling. Fish at Kendall Creek Hatchery did not differ significantly in length one week after the initiation of experimental rearing (Fig. 1), though the control fish did weigh significantly more than their seminatural counterparts ( $P = 0.021$ ; Fig. 2). By the second sampling period, five weeks after the beginning of the experiment, fish did not differ in either length or weight, and this similarity continued throughout the duration of rearing. At experiment initiation, fish at Soos Creek Hatchery differed significantly in length ( $P = 0.025$ ; Fig. 3) but not in weight (Fig. 4). Size had evened out by the second sampling period, and fish remained similar in size for the duration of rearing. Minter Creek Hatchery fish differed in weight ( $P = 0.029$ ), but not in

length ( $P = 0.076$ ) two weeks after initiation of experimental rearing (Figs. 5 and 6). These differences had disappeared by the second sampling period, and did not develop again. In summary, the trend at all three rearing facilities was for the size difference between the treatments to close by time of release.

Even at first sampling the color of the fish in the two rearing treatments differed on at least one of the three color axes (hue, saturation, and intensity). At Kendall Creek, both hue and intensity were statistically similar one week after ponding, but saturation was significantly different ( $P = 0.000$ ; Figs. 7, 8, and 9). The difference in this variable was maintained throughout rearing. Significant differences developed in hue by the second sampling period, and differences in intensity did not appear until the third sampling period. One week prior to release, again only two of the three variables differed significantly, with intensity being no longer significant ( $P = 0.053$ ).

At Soos Creek saturation was also the only one of the three coloration variables to differ significantly at the first sampling period ( $P = 0.005$ ; Figs. 10, 11, and 12). Differences in hue were not detected until the last coloration sample, but intensity differences were significant ( $P = 0.008$ ) by the second sampling period. All three color axes were significantly different at the final sample.

At Minter Creek neither hue nor saturation differed significantly in the first coloration sample (Figs. 13 and 14), though intensity was significantly different ( $P = 0.000$ ; Fig. 15). All three color axes were significantly different one month later. The final coloration data for the photographs taken on 14 May 2001 have not yet been analyzed.

In summary, by release, it appears measurable color differences had developed between the fish in the two rearing treatments at all three experimental facilities.

In 2001, there were no consistent or major differences in the health of the fish in the two rearing treatments. At Kendall Creek Hatchery no statistically significant differences were detected in fish condition by the Goede Index (Figs. 16, 17, 18, and 19), except in the amount of hematocrit in the blood. Fish from the seminatural raceway displayed higher red blood cell counts ( $P = 0.005$ ; Fig. 17). At Soos Creek Hatchery the only variable to show significant differences from the fish condition profile was the bile ( $P = 0.010$ ; Fig. 20). None of the blood variables were statistically different (Figs. 21, 22, and 23). At Minter Creek Hatchery there were no detectable differences in the fish condition profile (Figs. 24, 25, 26, and 27).

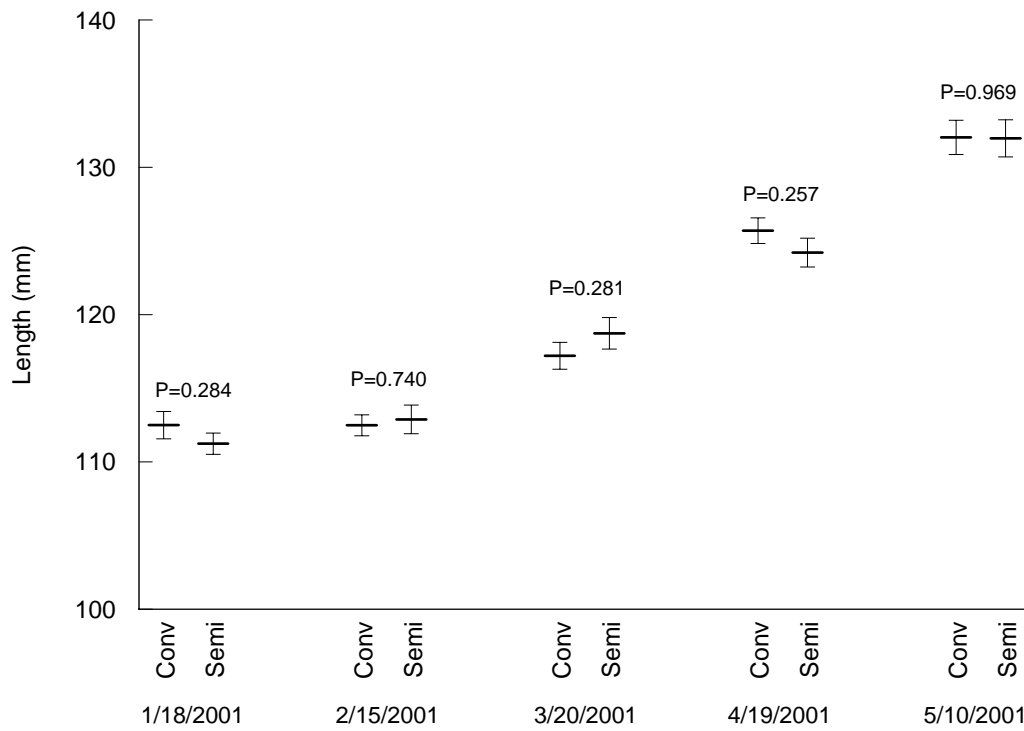


Figure 1. Mean length (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Kendall Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 5/10/2001). P values are based on *t*-tests.

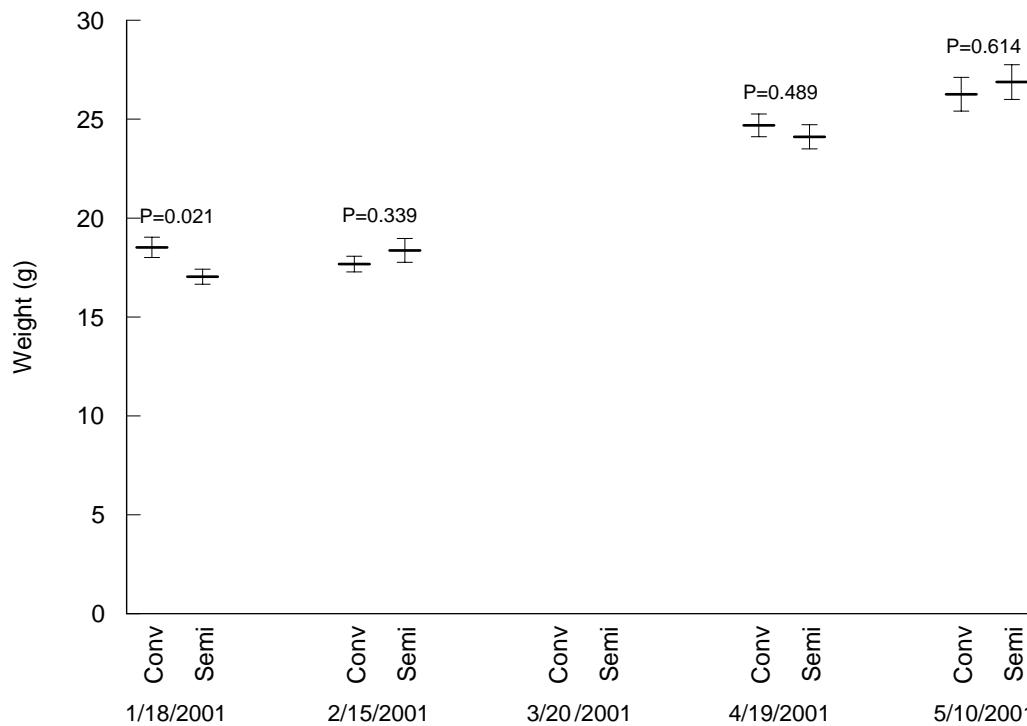


Figure 2. Mean weight (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Kendall Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 5/10/2001). P values are based on *t*-tests.

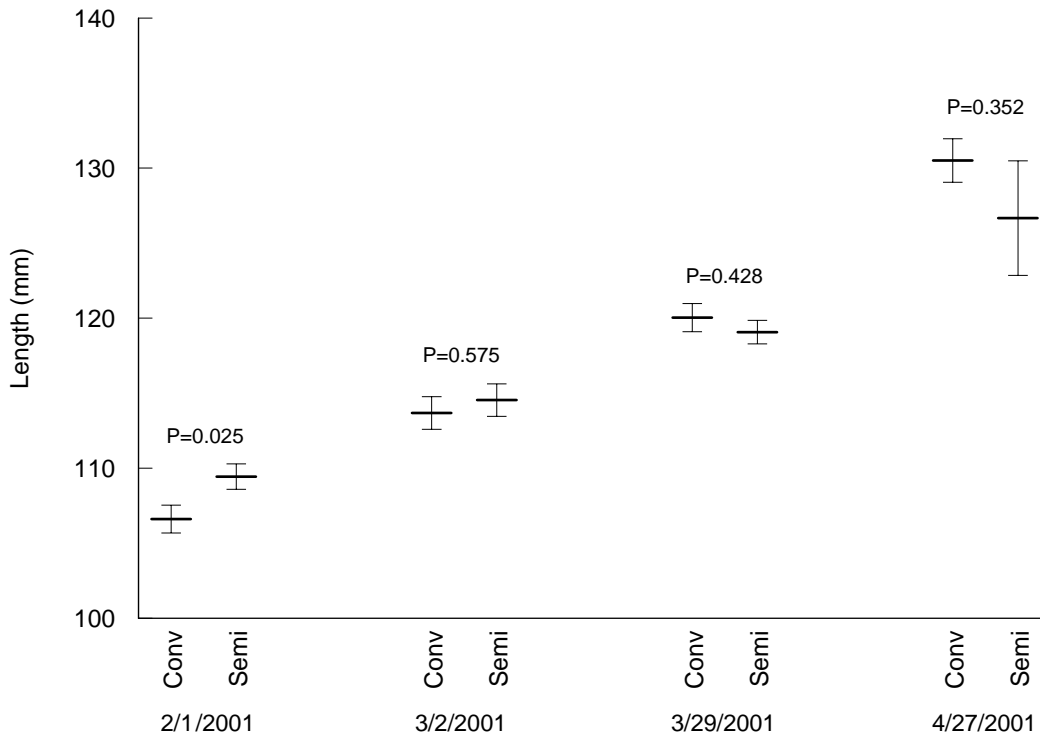


Figure 3. Mean length (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Soos Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 4/27/2001). P values are based on *t*-tests.

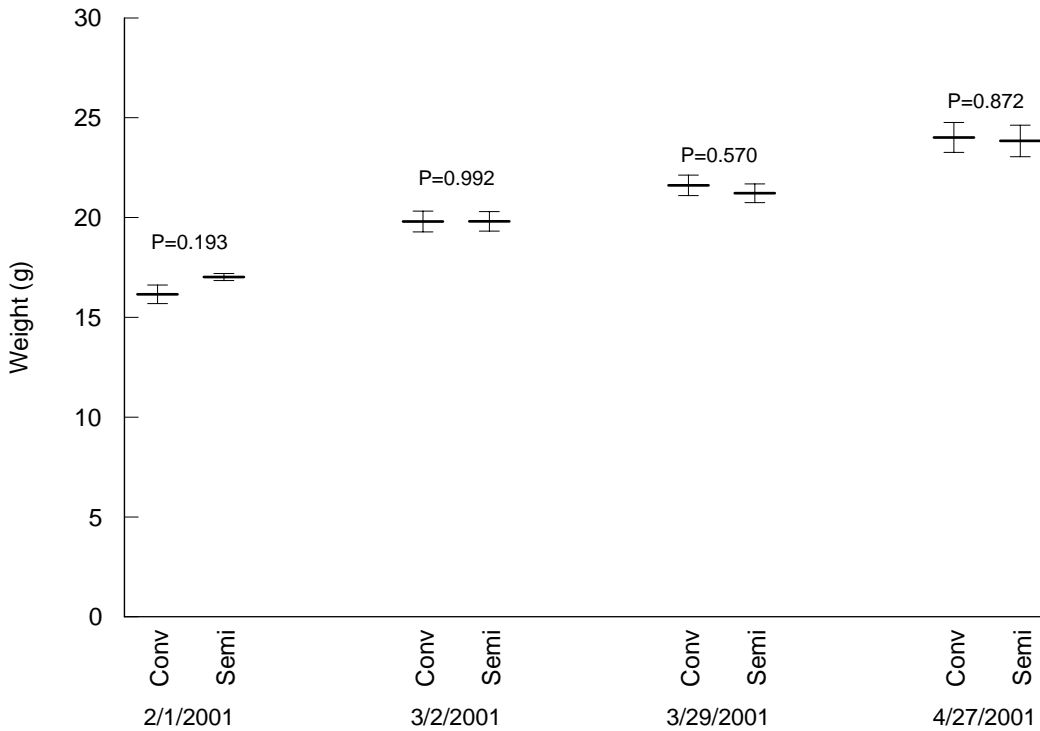


Figure 4. Mean weight (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Soos Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 4/27/2001). P values are based on *t*-tests.

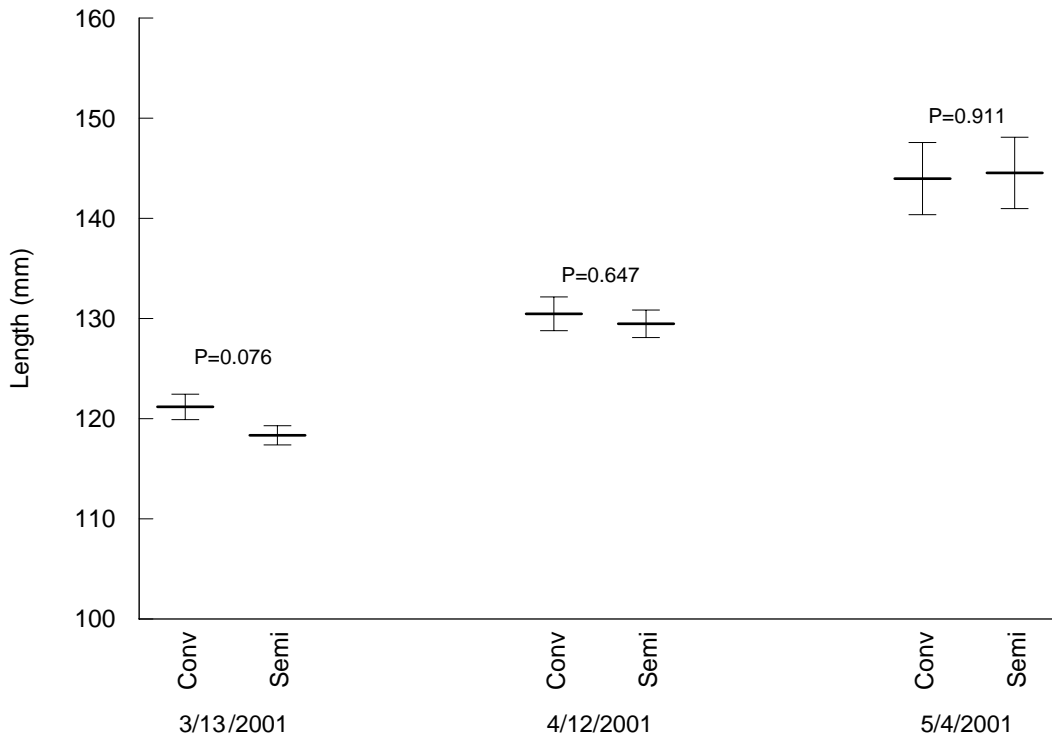


Figure 5. Mean length (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Minter Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 5/4/2001). P values are based on *t*-tests.

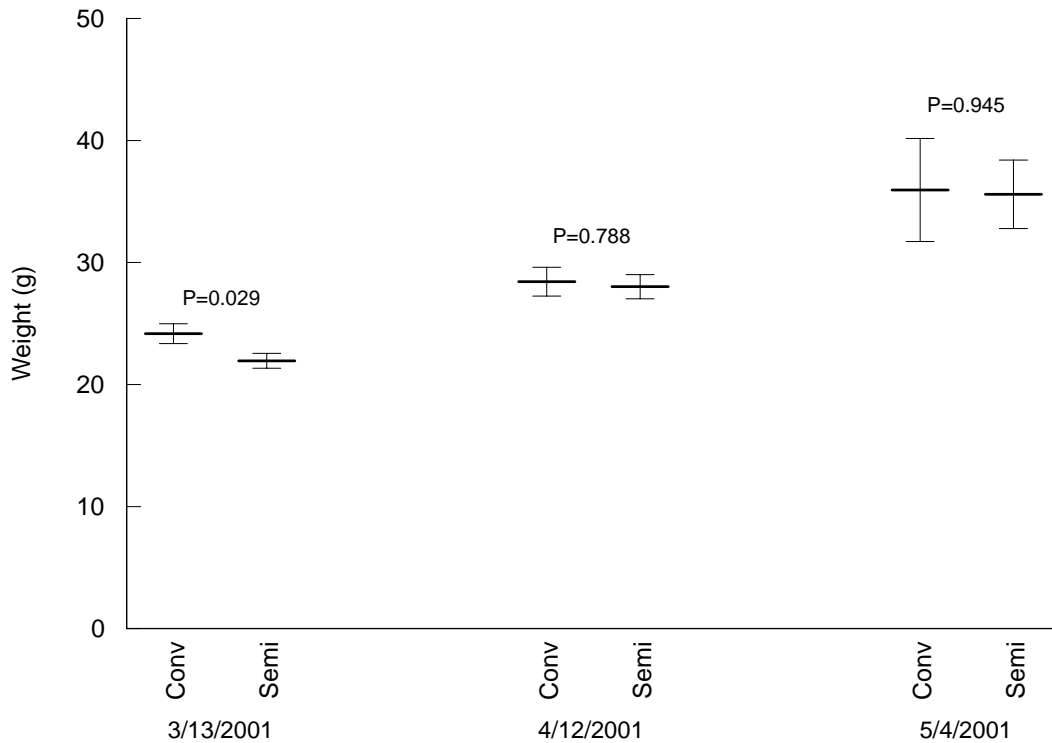


Figure 6. Mean weight (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Minter Creek Hatchery in 2001 (N = 100 per treatment, except N = 30 per treatment on 5/4/2001). P values are based on *t*-tests.

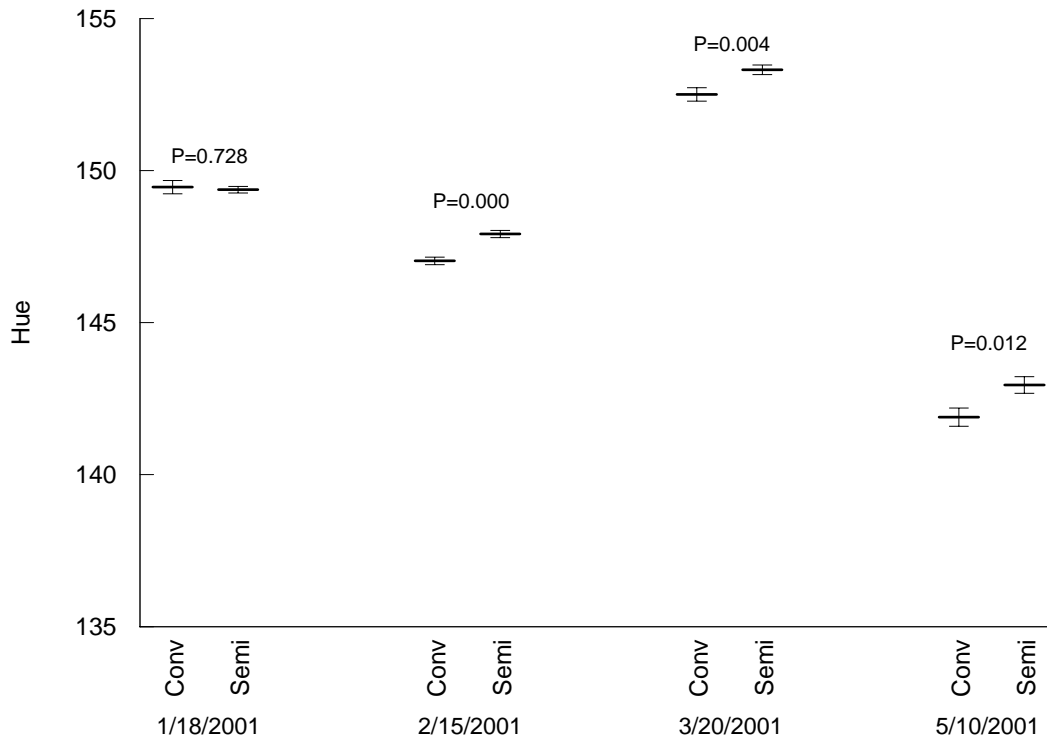


Figure 7. Mean hue values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Kendall Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

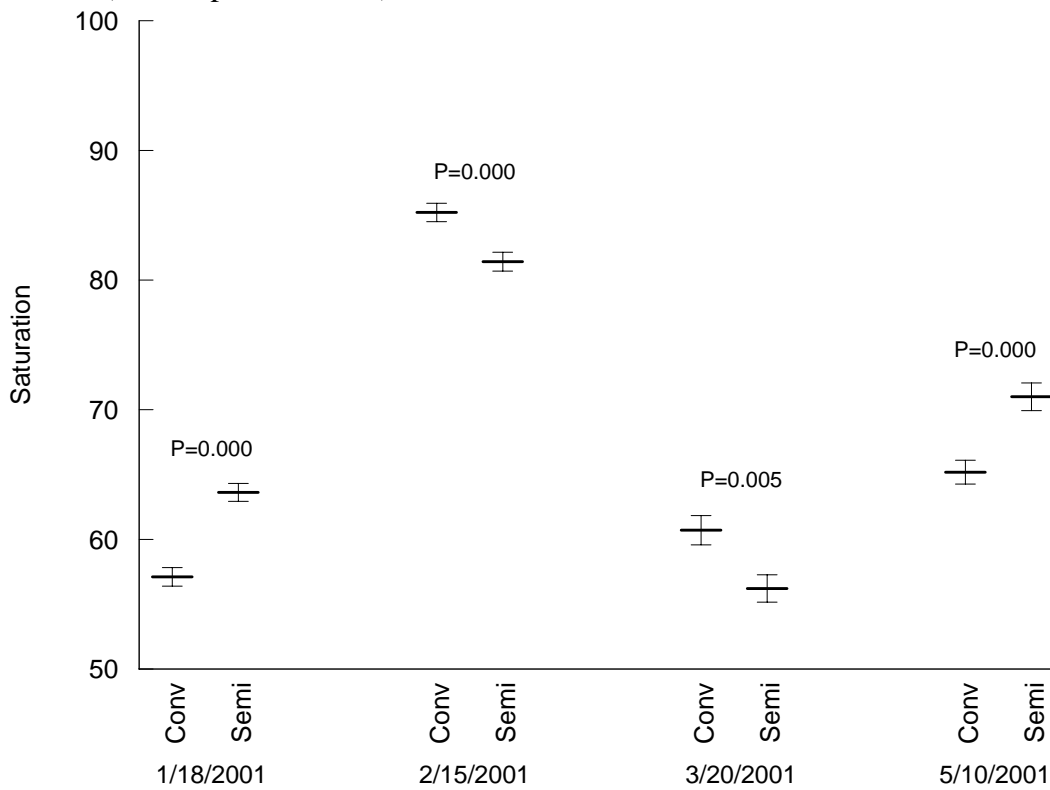


Figure 8. Mean saturation values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Kendall Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

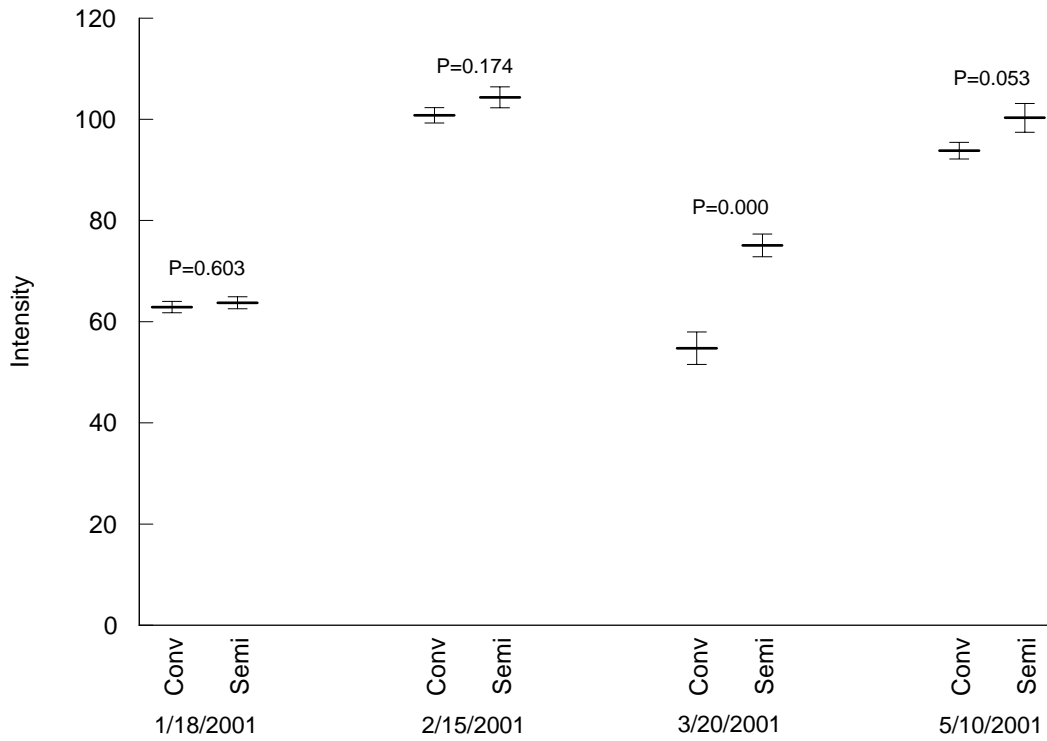


Figure 9. Mean intensity values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Kendall Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

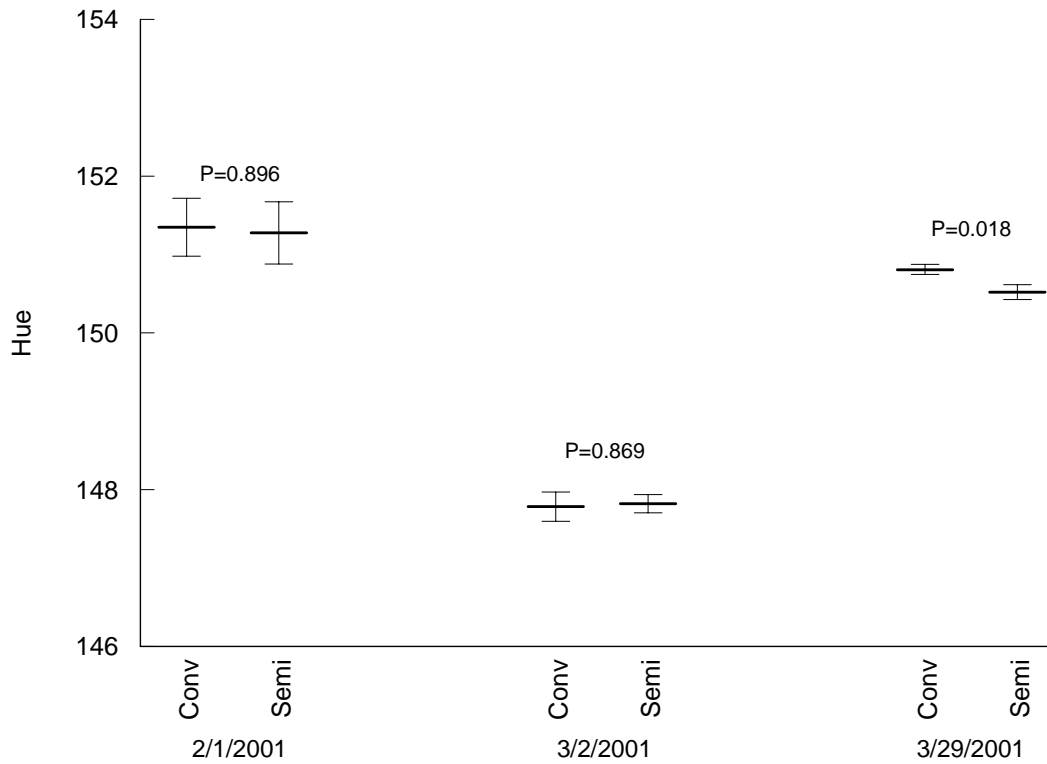


Figure 10. Mean hue values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Soos Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

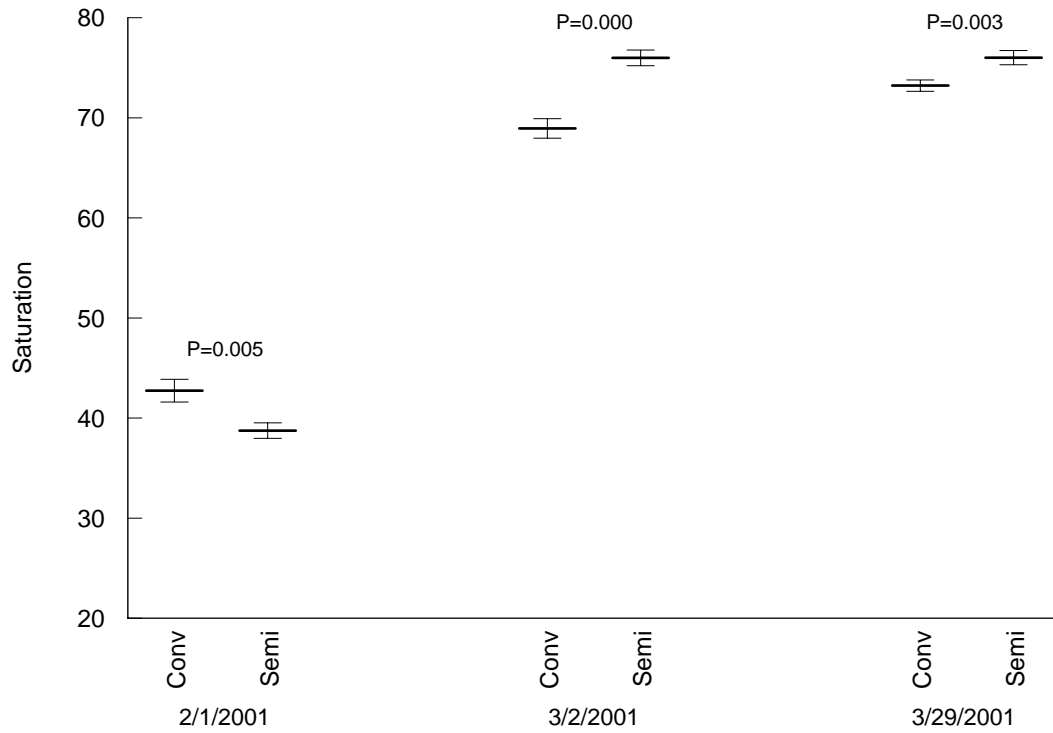


Figure 11. Mean saturation values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Soos Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

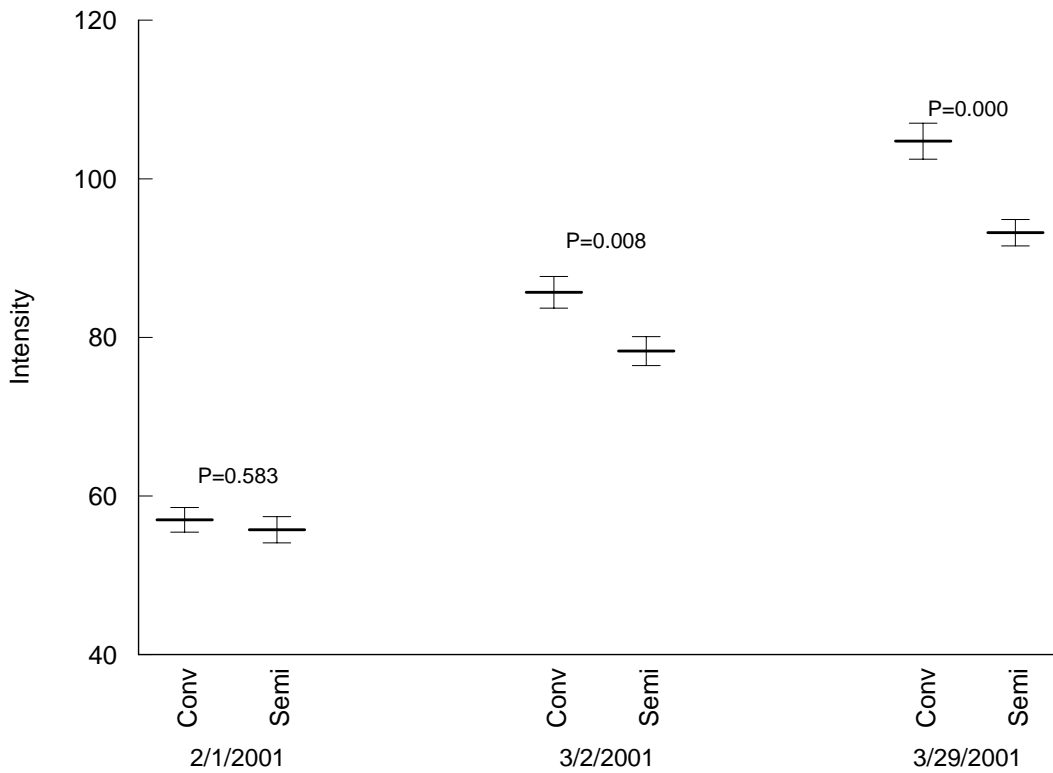


Figure 12. Mean intensity values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Soos Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

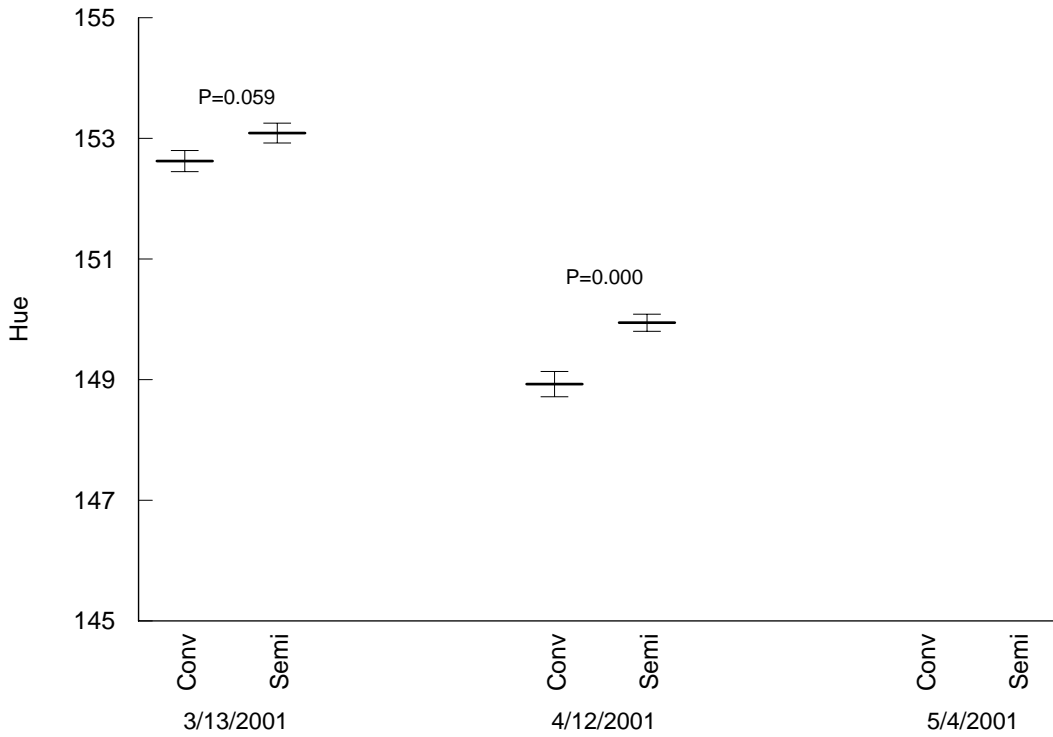


Figure 13. Mean hue values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Minter Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

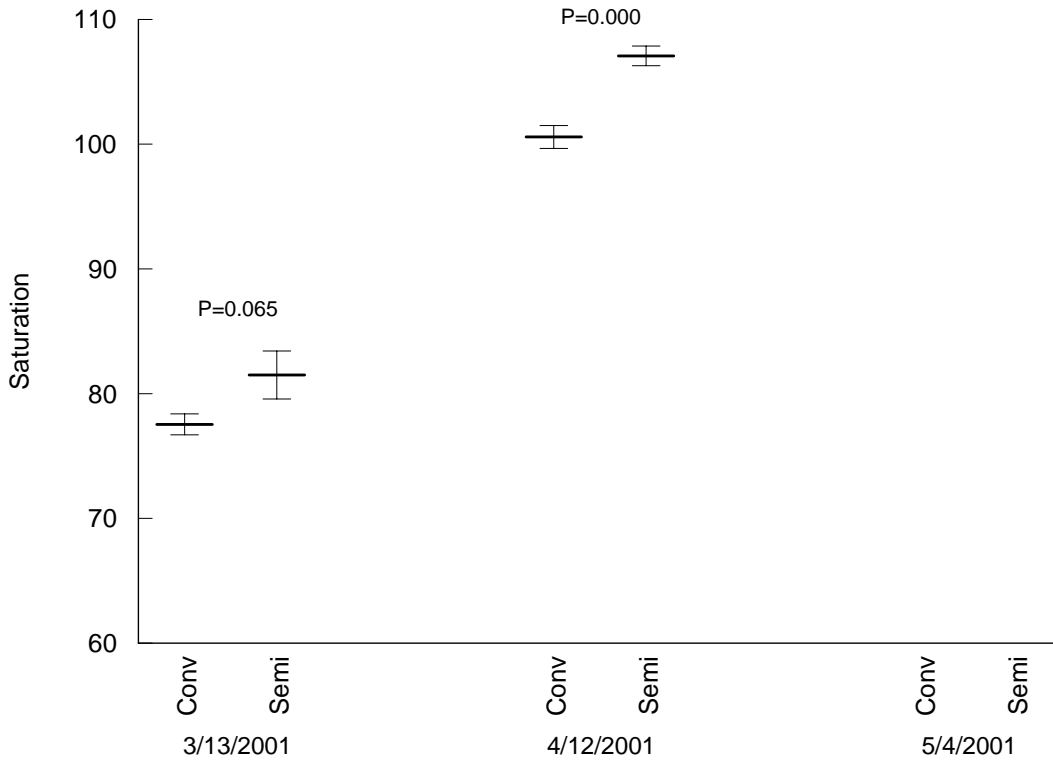


Figure 14. Mean saturation values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Minter Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

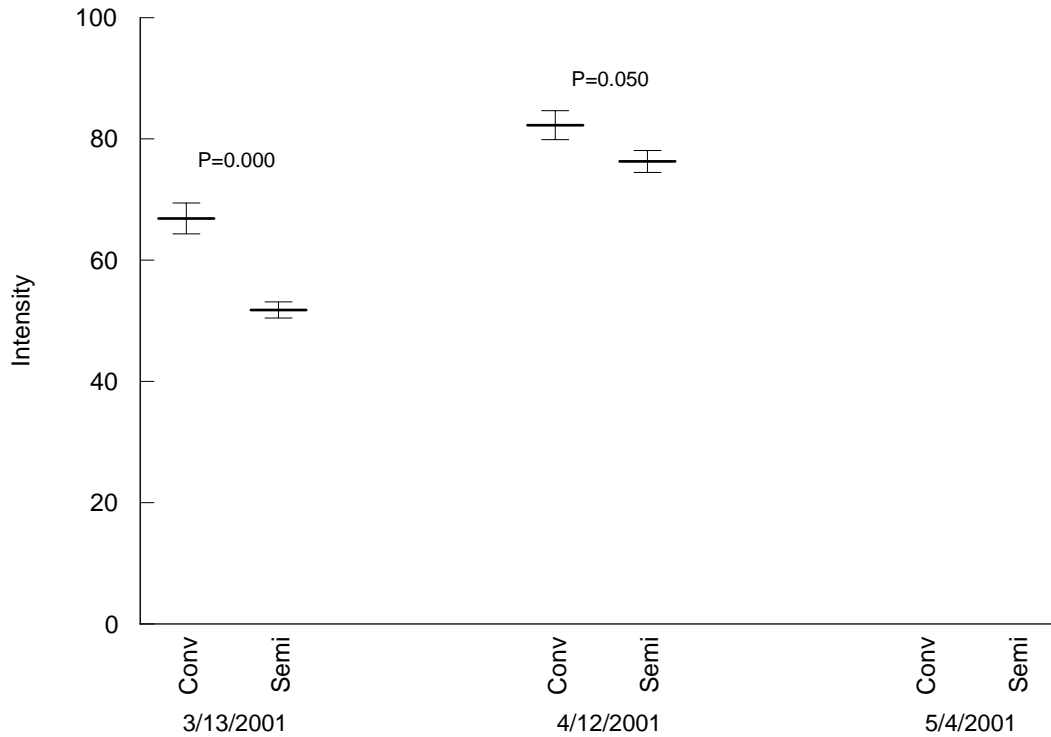


Figure 15. Mean intensity values (with standard error bars) of coho salmon throughout rearing in seminatural or conventional raceways at Minter Creek Hatchery in 2001 (N = 30 per treatment). P values are based on *t*-tests.

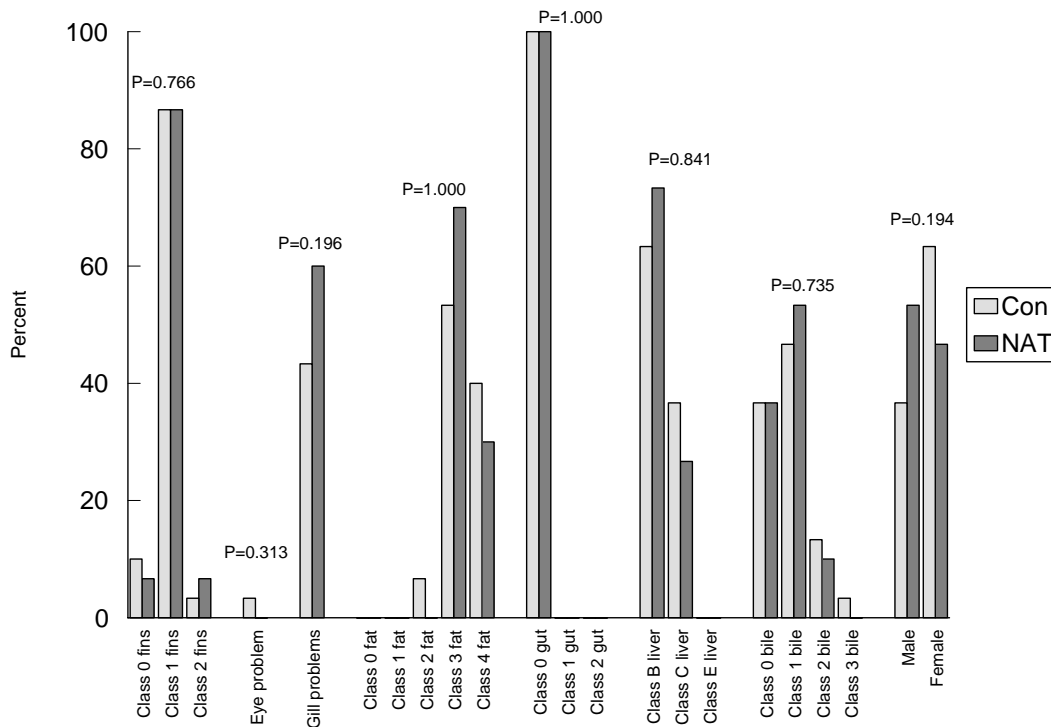


Figure 16. Percentage of coho salmon in different classes or showing problems in the 10 May 2001 Kendall Creek fish condition profile (Goede Index). Fish were reared in seminatural (NAT, N = 30) or conventional (Con, N = 30) raceways. P values are based on contingency table analysis.

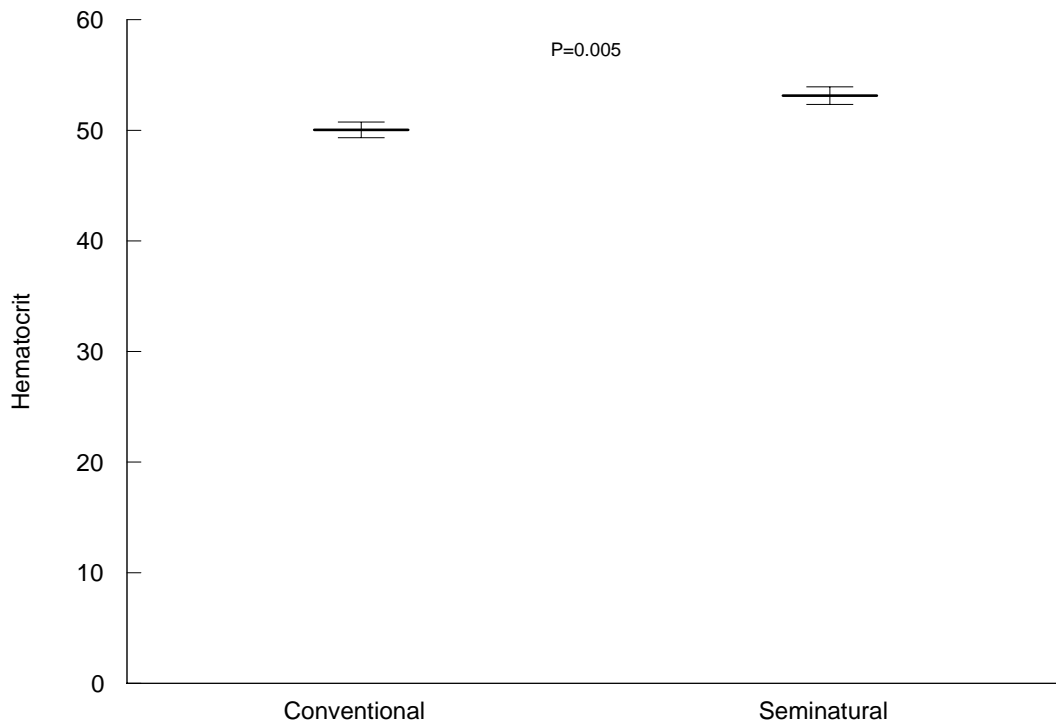


Figure 17. Mean hematocrit values (with standard error bars) of coho salmon reared in seminatural or conventional raceways at Kendall Creek Hatchery on 10 May 2001 (N = 30 per treatment). P value based on *t*-tests of arcsine transformed data.

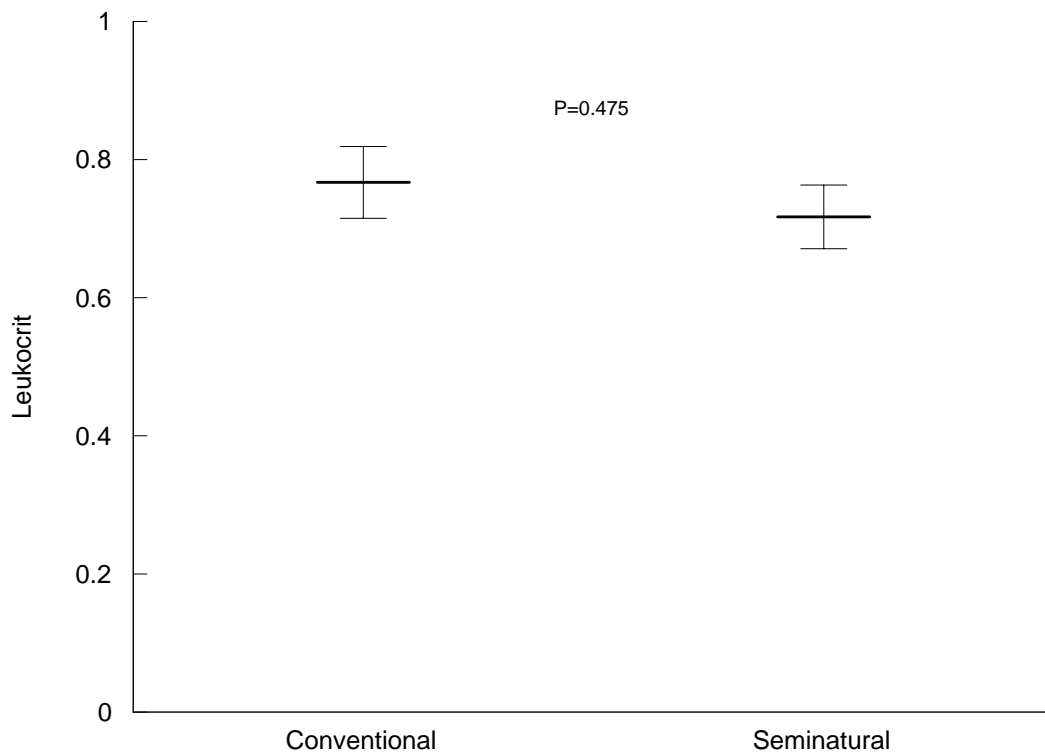


Figure 18. Mean leukocrit values (with standard error bars) of coho salmon reared in seminatural or conventional raceways at Kendall Creek Hatchery on 10 May 2001 (N = 30 per treatment). P value based on *t*-tests.

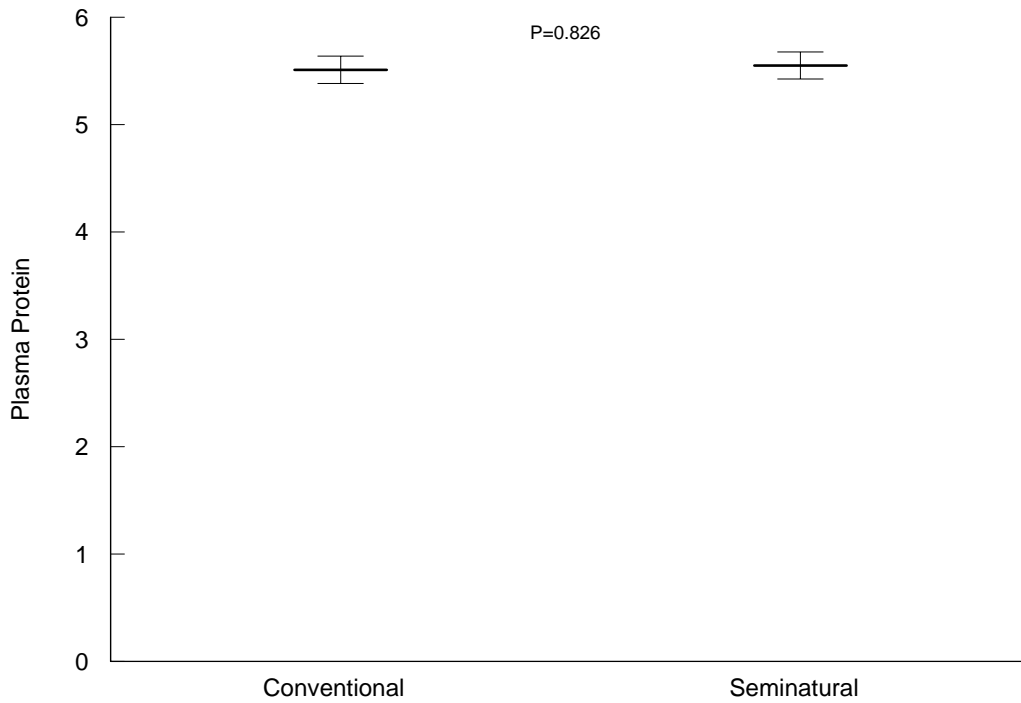


Figure 19. Mean plasma protein values (with standard error bars) of coho salmon reared in seminatural (N = 28) or conventional (N = 29) raceways at Kendall Creek Hatchery on 10 May 2001. P value based on *t*-tests.

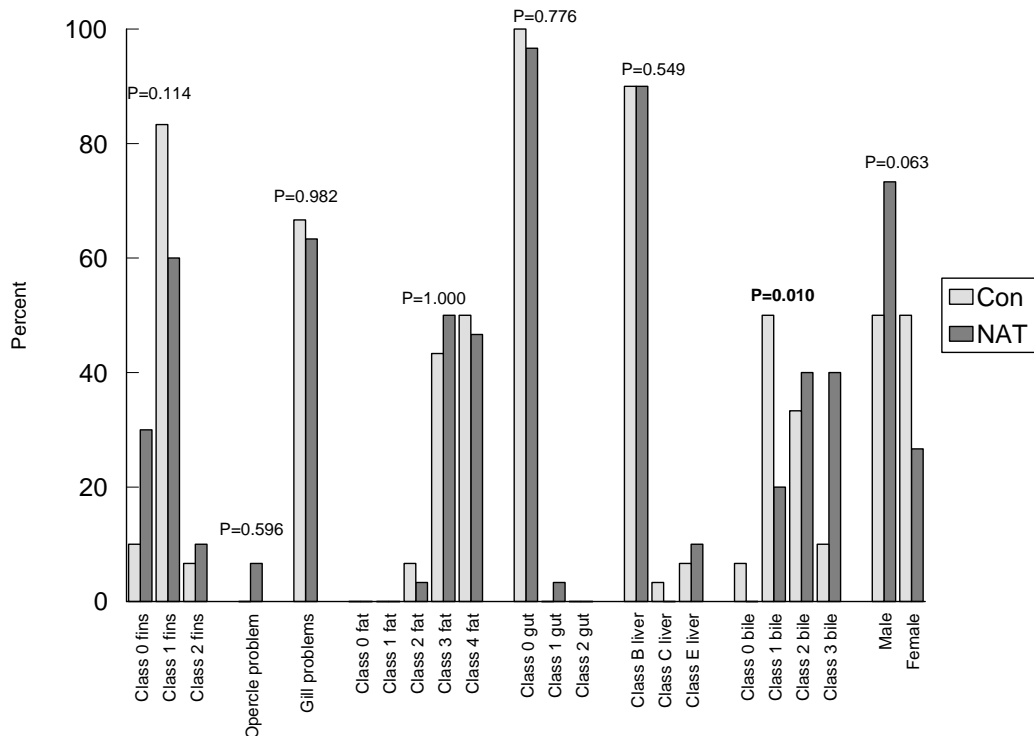


Figure 20. Percentage of coho salmon in different classes or showing problems in the 27 April 2001 Soos Creek fish condition profile (Goede Index). Fish were reared in seminatural (NAT, N = 30) or conventional (Con, N = 30) raceways. P values are based on contingency table analysis.

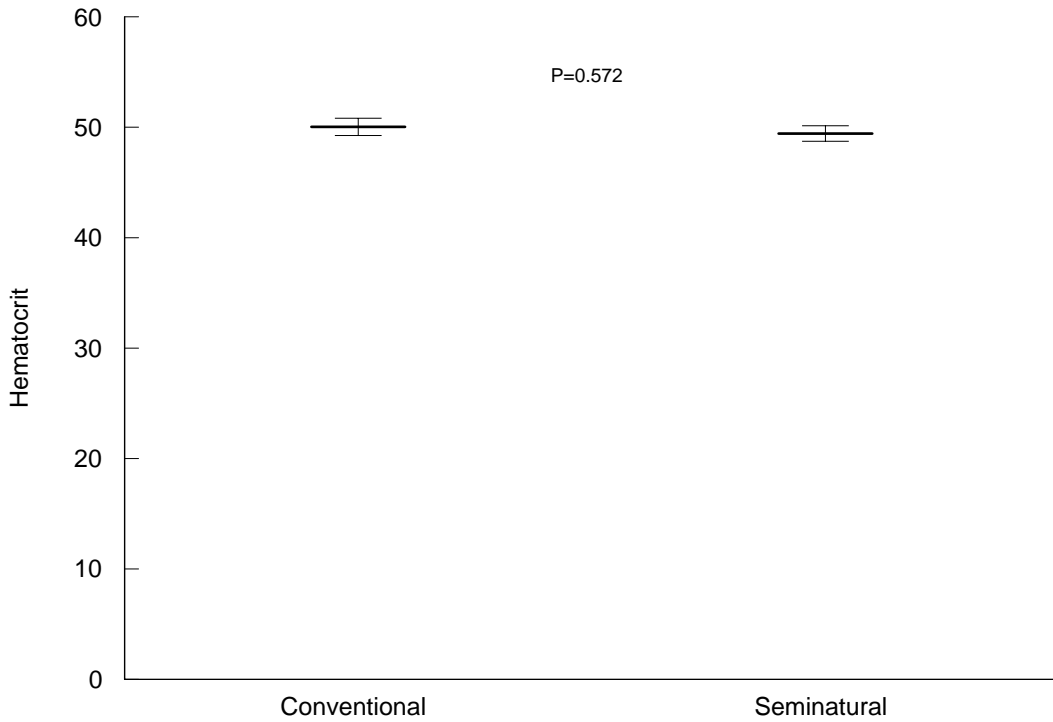


Figure 21. Mean hematocrit values (with standard error bars) of coho salmon reared in seminatural or conventional raceways at Soos Creek Hatchery on 27 April 2001 (N = 30 per treatment). P value based on *t*-tests of arcsine transformed data.

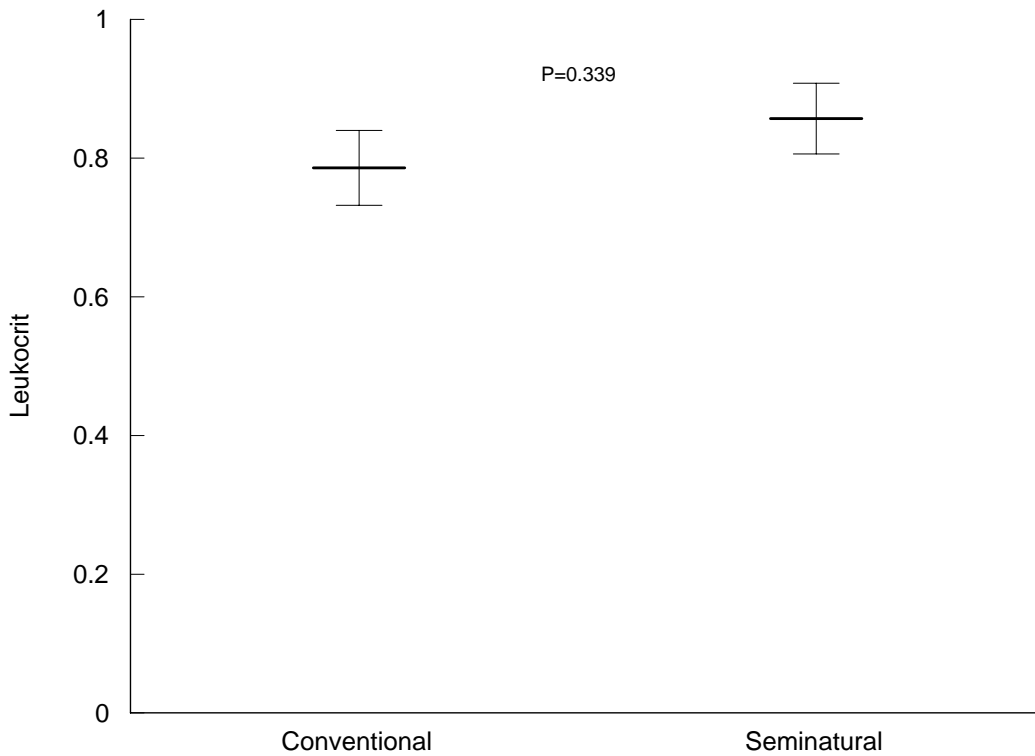


Figure 22. Mean leukocrit values (with standard error bars) of coho salmon reared in seminatural or conventional raceways at Soos Creek Hatchery on 27 April 2001 (N = 28 per treatment). P value based on *t*-tests.

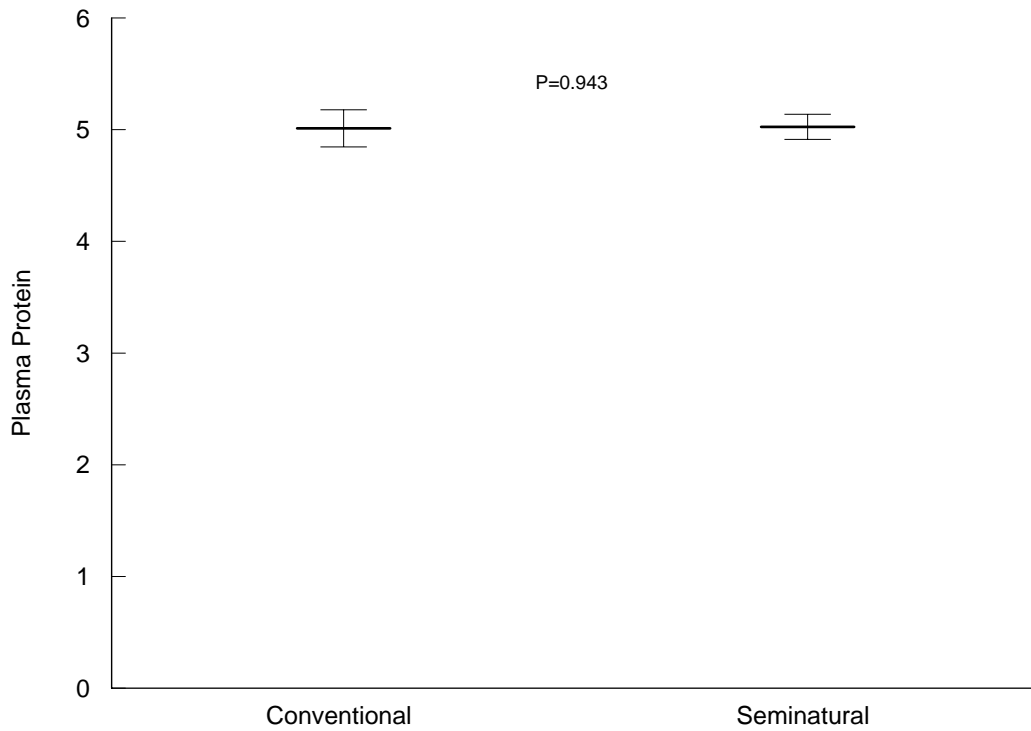


Figure 23. Mean plasma protein values (with standard error bars) of coho salmon reared in seminatural or conventional raceways at Soos Creek Hatchery on 27 April 2001 (N = 28 per treatment). P value based on *t*-tests.

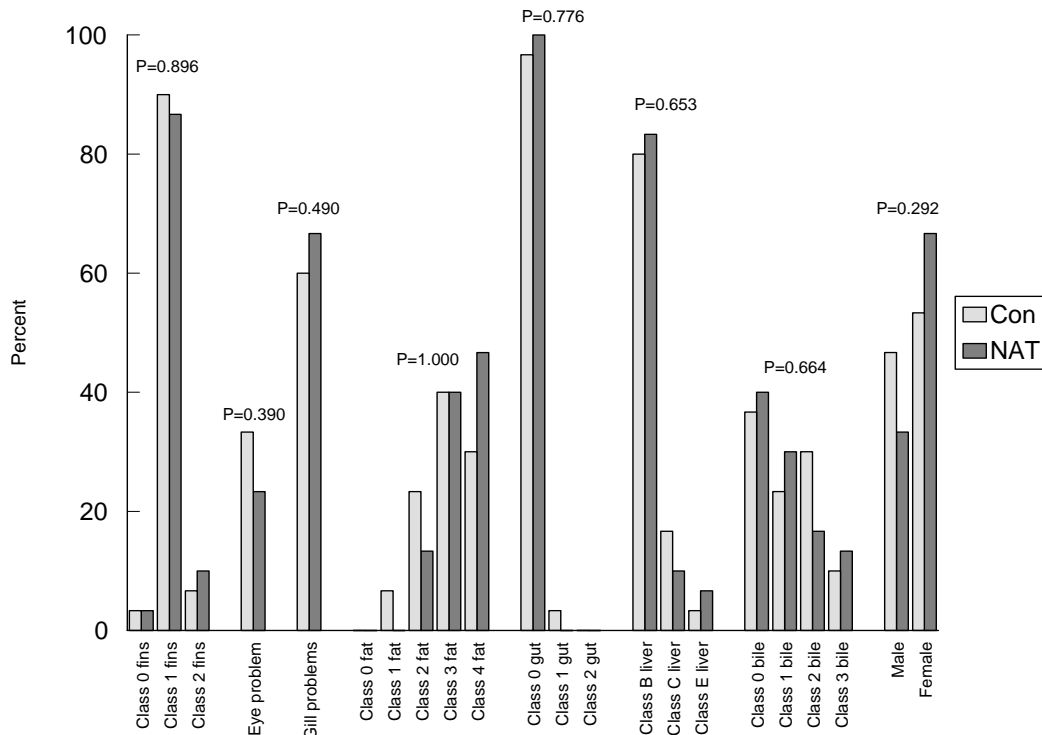


Figure 24. Percentage of coho salmon in different classes or showing problems in the 4 May 2001 Minter Creek fish condition profile (Goede Index). Fish were reared in seminatural (NAT, N = 30) or conventional (Con, N = 30) raceways. P values are based on contingency table analysis.

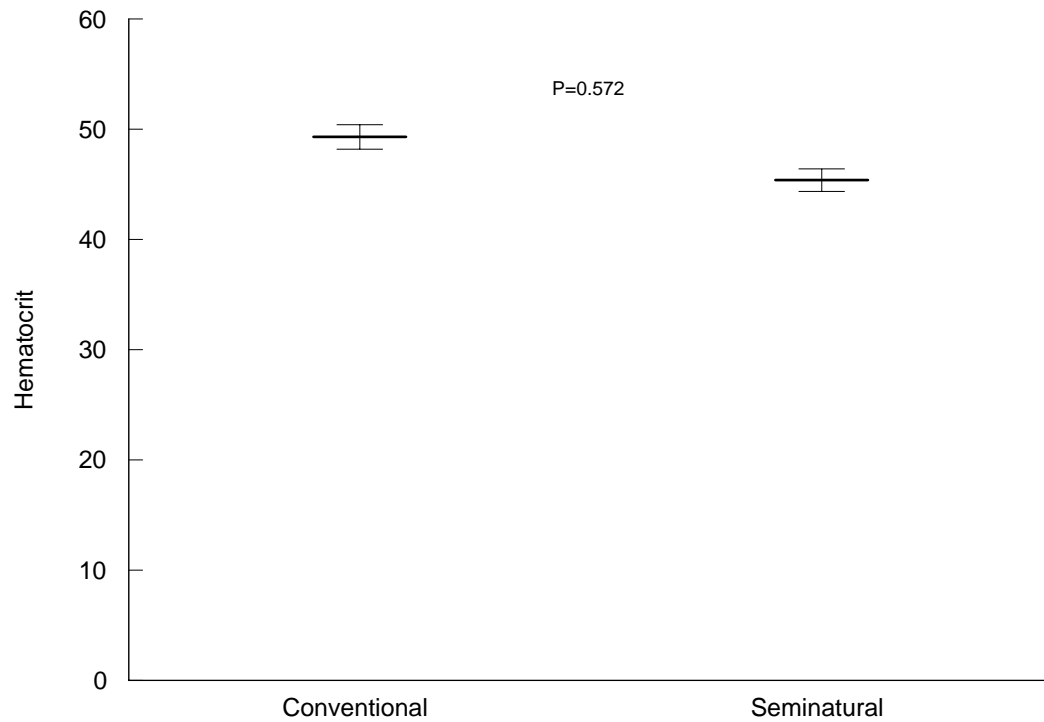


Figure 25. Mean hematocrit values (with standard error bars) of coho salmon reared in seminatural (N = 29) or conventional (N = 30) raceways at Minter Creek Hatchery on 4 May 2001. P value based on *t*-tests of arcsine transformed data.

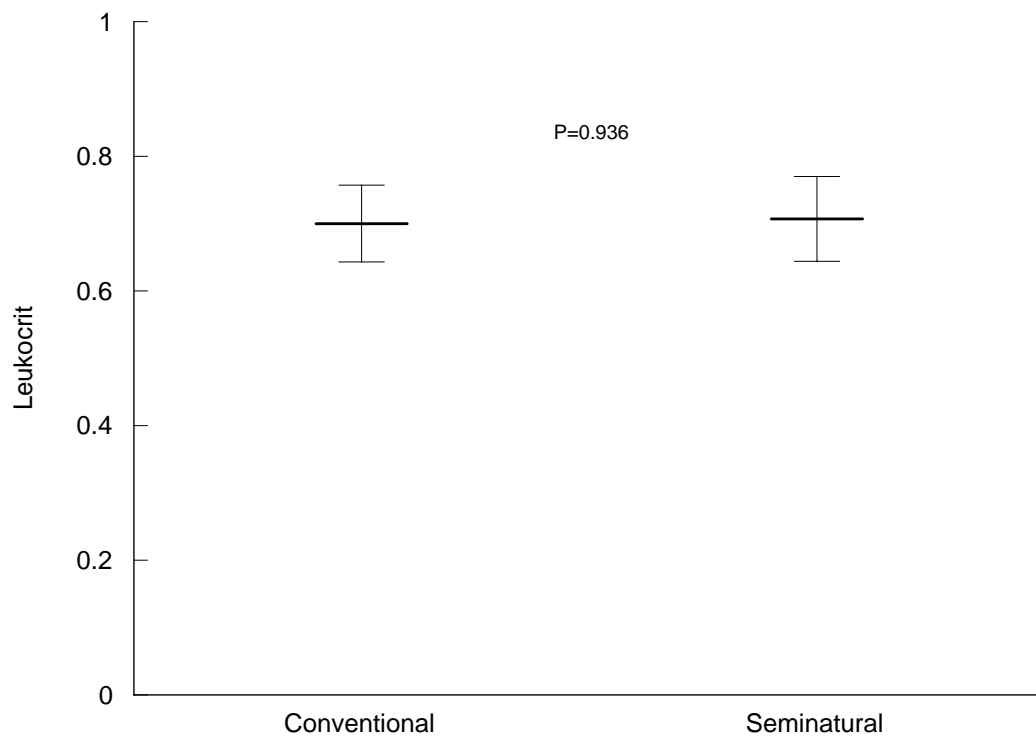


Figure 26. Mean leukocrit values (with standard error bars) of coho salmon reared in seminatural (N = 29) or conventional (N = 30) raceways at Minter Creek Hatchery on 4 May 2001. P value based on *t*-tests.

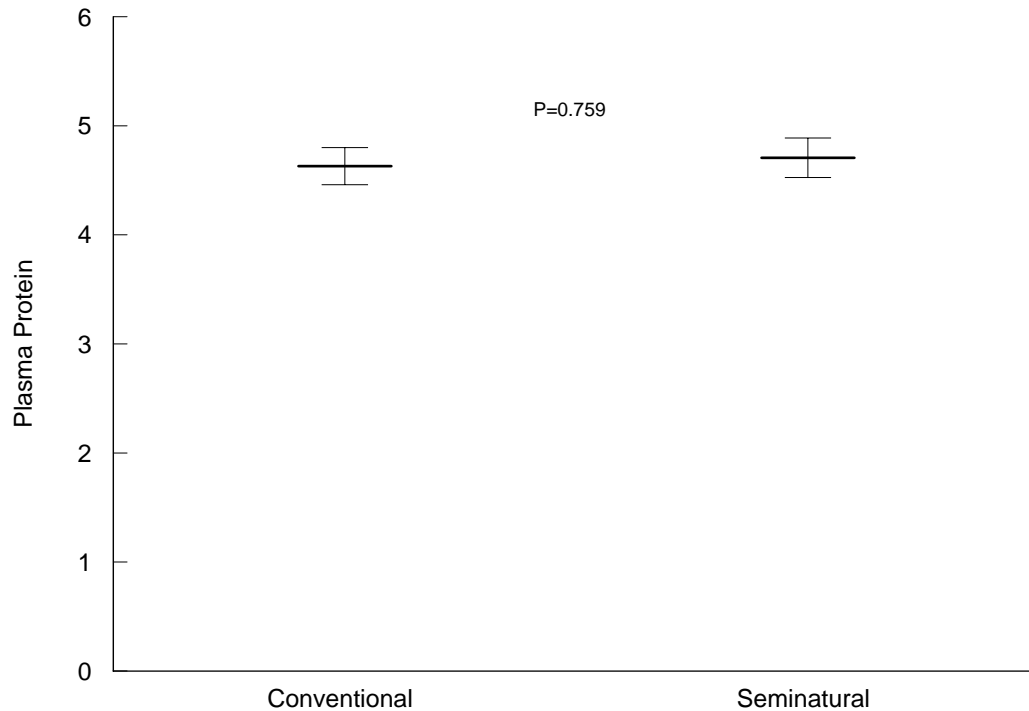


Figure 27. Mean plasma protein values (with standard error bars) of coho salmon reared in seminatural (N = 30) or conventional (N = 27) raceways at Minter Creek Hatchery on 4 May 2001. P value based on *t*-tests.

### Smolt-to-Adult Survival Evaluation

Data on returns of coho salmon released in 2001 will not be available until 2004.

### Discussion

The concrete pavers developed for the experimental rearing are a definite improvement over the resin rock pavers used in an earlier chinook salmon seminatural raceway habitat study. They cost less (\$6.00/ft<sup>2</sup> vs. \$10.00/ft<sup>2</sup>), are easier to install, are more readily cut with a concrete block saw, and are more durable with an anticipated life span of 10-years or more. In addition, their flat surface is easier to vacuum than the resin rock pavers and does not seem to produce a significant burden on hatchery staff. The only cleaning concern was the occasional loose rock that might be vacuumed up and jam the venturi nozzle on the vacuum system. These pavers appear to be more durable than painted surfaces, as the rock color does not fade with exposure to sunlight as has occurred with other environmental enrichment systems at production hatcheries such as Cle Elum (Craig Busack, WDFW, Olympia, WA 98501, Pers. commun., February 2001) and Sawtooth (Desmond Maynard, unpubl. data. NMFS, Manchester Research Station, Port Orchard, WA 98366). In addition, there is enough rugosity to concrete pavers that food waste, fecal material, and sediment settles between the rock interstices, rather than covering over the entire surface as occurs with painted ponds. In addition to ensuring the substrate is not covered over, this settling of debris in the spaces between gravel may provide a cleaner water column as observed in earlier chinook salmon experiments with gravel substrate (Maynard et al. 1996a). The only improvement to be made would be to

move from hand to machine manufacture to lower manufacturing costs. Engineering estimates put material costs at less than \$2.00/ft<sup>2</sup>.

All three cover systems used this year met the criteria of covering the raceways, while providing a mechanism for hatchery staff to access the raceways for feeding, vacuuming, and removal of fish mortalities. The hinged covers at Soos Creek Hatchery were the easiest to operate and required minimal maintenance. The roller frame covers at Minter Creek Hatchery were the most problematic. The wind would blow them back and forth on the track, as well as blow them off the track, and they were the only covers that did not survive a heavy snow load. We believe these problems with the Minter Creek Hatchery covers can be solved with some minor design changes that will be implemented next year. The Kendall Creek Hatchery covers required the most effort to operate with personnel having to lift one side of each suspended cover and tie off ropes to hold that side up in the air while they accessed the raceway for cleaning or feeding. However, they were the least complex and could be made at a lower cost than hinged covers used at Soos Creek Hatchery. They are being replaced with hinged covers because of the extra burden they place on the hatchery staff and their suspension framework probably cannot support the predator netting when pulled down by heavy snow loads.

The fir tree instream structure was almost problem free. It required no maintenance and hatchery personnel could vacuum the raceways with it present. It now appears that we have developed a seminatural raceway habitat that can be successfully operated by fish culturists at production hatcheries, as all fish culture and raceway maintenance in this study was conducted by hatchery personnel, rather than research scientists.

The growth profiles of the fish in this study are different than that observed in past seminatural raceway habitat studies. The initial size difference at ponding probably resulted from unknown conditions existing prior to the fish being placed in the experimental ponds. Given their magnitude, it is unlikely differences developed in the short time between ponding and first sampling. It is more likely that the closing of size differences between the rearing treatments is due to treatment effects. At Kendall and Minter Creek Hatcheries the closing, if anything, was the result of seminaturally reared fish catching up with the conventionally reared fish. At Soos Creek Hatchery this was reversed with conventionally reared fish catching up with the seminaturally reared fish. In most of our previous chinook salmon studies the trend was for conventionally reared fish to grow faster than seminaturally reared fish (Maynard et al. 1996 a, c, d). With that species the different growth profile was attributed to their reluctance to feed on food that has fallen into spaces between the gravel in the seminatural raceways. However, hatchery coho are not known to be reluctant to pick food up off the bottom and at two of the three facilities seminaturally reared fish appeared to be growing faster. Therefore, with coho salmon, we can not advance any logical explanation for this potential growth difference between the treatments at this point in time.

The development of color differences between the two rearing treatments is similar to that which has been observed in studies with chinook salmon (Maynard et al. 1996 a, c). Presumably seminatural raceway habitat rearing is producing coho salmon with better camouflage coloration for the stream, river, and estuarine postrelease backgrounds where they are released. Theoretically this enhanced camouflage will

increase their postrelease survival by reducing their vulnerability to visually hunting predators (birds and fish) during the first few weeks following release. However, it will remain unknown whether this enhanced camouflage truly increases postrelease survival until 2004 when smolt-to-adult survival data become available.

As in past experiments, the health of the fish in seminatural and conventional raceway habitat appeared to be similar. The differences that did occur were not consistent across all three rearing facilities, suggesting major treatment differences do not exist.

The preliminary study findings indicate that seminatural raceway habitat can be operated at production scale facilities and produce beneficial biological rearing effects in coho salmon similar to those that seem to improve the instream postrelease survival of chinook salmon. Fishery managers can use this increased postrelease survival to improve hatchery efficiency, increase harvest, speed the rebuilding of self-sustaining natural runs through supplementation, or simply reduce the ecological impact of hatchery fish by lowering release numbers while maintaining recruitment.

Three more years of rearing and release are required to complete the original experimental design. This will include adding two additional hatcheries (Issaquah and Sol Duc) in 2001 to compensate for the raceways at Issaquah Hatchery not being available in 2000. Beginning in 2002 it may be possible to monitor instream survival from Issaquah Hatchery using the PIT-tag detector system present on the Lake Washington Ship Canal. This would only require additional tagging work and would provide guidance until the adult return data was complete.

## **EVALUATION**

The study successfully attained all its first year objectives. Seminatural raceway habitat compatible with routine fish culture activities and suitable for use in production raceways was developed and installed at all three facilities. At each of these facilities fish were successfully reared in the experimental environments for at least two months. The growth, color development, and health of fish in the two rearing treatments was successfully followed and compared. Finally, the experimental fish have been coded-wire tagged and released to the sea to determine the effects of seminatural raceway habitat on their smolt-to-adult survival. In summary, all necessary activities (rearing, tagging, etc.) to compare smolt-to-adult survival of the two rearing treatments when they return have been successfully accomplished in 2001. The preliminary findings have been disseminated at the HSRG 2001 program review. In addition, interim findings will be presented at fish culture conferences and scientific meetings. The final project results will be disseminated in peer reviewed publications.

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