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Performance and behavior of cutthroat trout (*Oncorhynchus clarki*) reared in covered raceways or demand fed

Eric J. Wagner *, David A. Ross [1], Douglas Routledge, Brian Scheer, Thomas Bosakowski [2]

Fisheries Experiment Station, Utah Division of Wildlife Resources, 1465 West 200 North, Logan, UT, USA

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Abstract

Cutthroat trout (*Oncorhynchus clarki* utah) were reared in outdoor raceways with or without plywood covers. The same hand-fed controls for this experiment were also used to test the effects of demand feeding. Growth, feed conversion, and mortality did not differ ($P > 0.05$) among the hand-fed covered, hand-fed uncovered (control), and demand-fed groups after 256 days. Autopsy-based parameters were generally not significantly different among groups. However, hematocrit and the fat index were significantly higher in covered raceways after 166 days. The fin index was significantly lower in covered raceways on both Day 166 and 225. Pectoral fin erosion was significantly reduced in covered raceways relative to controls by Day 166, but did not differ by Day 225. Demand feeding did not improve fin condition. Observations of cover preference were made for four fish groups over a 45 min period, either in the presence of a stuffed eagle or without it. All groups significantly preferred cover, but there were no differences related to rearing under cover or the presence of a predator model. Covers did improve fin condition and fat levels of fish during early rearing, but the benefits were not sustained throughout the rearing period. Use of demand feeders did not produce tangible health or growth benefits, but did not negatively impact the fish either. Demand feeding reduced the labor required to feed the fish, but increased cleaning time.

Keywords: Fin erosion; Demand feeding; *Oncorhynchus clarki*

1. Introduction

Salmonids in nature are known to prefer cover (concealment), depending upon the species and temperature (Butler and Hawthorne, 1968; DeVore and White, 1978), size of

* Corresponding author.
[1] Utah Division of Wildlife Resources, 515 E. 5300 South, Ogden, Utah, USA
[2] Beak Consultants, 12931 N.E.126th Place, Kirkland, Washington, USA

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the cover (Heggenes and Traaen, 1988), age of the fish (Kwain and MacCrimmon, 1969), and the light intensity (Woodhead, 1957; Gibson and Keenleyside, 1966). Preference by salmonids for low light intensities is often ignored in intensive outdoor fish culture, although some fish culturists in the Utah state hatchery program do cover portions of raceways.

Research on the effects of cover in aquaculture has been inconclusive. Covers on concrete troughs did not affect growth or mortality of coho salmon (*Oncorhynchus kisutch*) alevins, but the combination of cover and substrate resulted in a higher mean weight than that of alevins in uncovered troughs with the plastic substrate (Fuss and Johnson, 1988). Channel catfish (*Ictalurus punctatus*) cultured in circular tanks with or without covers did not differ in growth, feed conversion, or survival (Allen, 1973). Research with lake trout (*Salvelinus namaycush*), reared in covered or uncovered rearing troughs and fed by hand or demand feeders, indicated that fish in covered raceways and hand-fed were heavier and more active when startled (Roadhouse et al., 1986). Problems with sunburn lesions in Atlantic salmon (*Salmo salar*) were solved when circular pools were covered with saran cloth providing 90% shade (Corson and Brezosky, 1961). Hatchery manuals also advise against exposure of eggs and alevins to direct sunlight (Piper et al., 1986).

This study compared the performance, health, and condition of fish between fully covered and uncovered raceways. The performance and health of fish from raceways with demand feeders were also compared to the hand-fed covered and uncovered treatments. In addition, this study evaluated cover selection by fish reared in either covered or uncovered raceways.

2. Materials and methods

Cutthroat trout (*Oncorhynchus clarki* utah) derived from the Bear Lake Bonneville strain were reared at the Fisheries Experiment Station from eggs supplied by the Mantua Hatchery, Mantua, Utah. On 17 August 1993 (Day 0 of the experiment), equal numbers (3085) of fish were stocked into each of six outdoor raceways (1.22 m × 11.58 m × 0.57 m deep) 71 days after hatching. Two raceways were completely covered and four were uncovered, except for nylon bird netting (hereafter referred to as uncovered). Covers were constructed of plywood, cut to fit within the raceway walls and nailed to wooden supports which crossed the width of the raceway. A crowding screen 2.74 m from the head of the raceway was accessed for cleaning through a hinged door from where fish were also fed. Efforts were made to scatter feed upstream under the cover to maximize consumption.

Measurements of light intensity at the surface of covered and uncovered raceways and of full sunlight were conducted with a light meter (Sper Scientific, Whatman Labs, Hillsboro, OR).

The initial mean weight of fish was 0.77 g each. Rations were initially hand fed, calculating the quantity for each raceway with the Hatchery Constant method (Buterbaugh and Willoughby, 1967). Care was taken to disburse feed to both covered and uncovered raceways similarly. When the fish reached a mean weight of about 9 g (Day 168, 2 February 1993), the fish in two raceways were provided with demand feeders for the remainder of the study. The demand feeders were continually replenished so fish could feed ad libitum. Statistical analysis of mean fish weight indicated no significant differences prior to initiating demand feeding. The frequency of hand feeding was initially three times a day, 5 days per week.

On Day 90, the frequency was changed to six times a day, 7 days per week. When the demand feeders were installed for use, the hand-feeding frequency was reduced to four times a day, 7 days per week. When a change in frequency was made, it was applied uniformly to all hand-fed treatments.

Water flows initially were 76 lpm and were increased periodically during the study period to a maximum of 250 lpm. Flow indices (Piper et al., 1986) during the study ranged from 0.17 to 1.01, and were at or below the maximum limits for the hatchery. The water temperature was either a constant 17°C or 12.6°C, some changes being necessary due to problems with a broken water main and low flows. The warm water was on initially, and changed to cold water on Day 119 where it remained until Day 167. Temperature changes were applied equally to all groups. Total hardness and total alkalinity were 239 and 222 mg l^{-1}, respectively. Dissolved oxygen during the latter period of the study was low at the tail end of the raceways (4.7–5.0 mg l^{-1}). This and another problem with a parasite (*Ichthyobodo*) infection prompted removal of a portion of the population from each raceway on Day 205 (21.4–40.5 kg removed per raceway), equalizing the number of fish remaining in each raceway. A salt treatment to control ectoparasites was applied to all raceways on Day 218.

The necropsy-based Health/Condition Profile (HCP; Goede and Barton, 1990) is a method for assessing general health and condition of fish by classifying visual observations of various organs and tissues into healthy or anomalous categories. The HCP also includes direct measurement of parameters such as total plasma protein, hematocrit, and leucocrit. HCP were conducted bimonthly, taking ten fish per raceway-replicate to give a 20 fish sample for each treatment. The HCP fin index was modified such that it ranged from 0 (fin intact) to 2 (severe fin erosion) instead of from 0 to 3 (Goede and Barton, 1990), and severity was a function of fin length and not hemorrhaging. On Days 166 and 225, the HCP sample was also used for measurement (nearest millimetre) of maximum fin lengths of all fins of all 20 fish (Kindschi, 1987). Fin measurements were made parallel to the fin rays. The adipose fin was measured from the anterior junction with the body to the rear of the lobe.

Mean fish weights were determined monthly for each raceway, based on a mean of three grab samples. Fish for this sample were crowded to the head end of the raceway with a screen and netted.

2.1. Observations of behavior

The influence of rearing fish under cover on behavior (cover preference) was tested using groups of four fish. The four fish were netted into the tank for each trial. The fiberglass observation tank (208 cm × 55 cm × 35 cm) had a plywood cover (69 cm × 55 cm) on one end, shading about a third of the tank. No water flowed into the tank during the observation period to avoid rheotaxic biases. The cover was alternated between ends of the tank to insure that selection was for cover and not tank related.

A video camera, which displayed the time of day on the video tape, was used to record the position of each fish relative to cover during 45 min trials. The fish were allowed 1 min to acclimate before observations began. Longer acclimation or observation periods were not considered because aggressive behavior began to influence fish position. After acclimation, the position of each fish was observed at 1 min intervals. This protocol was repeated ten times for each treatment (covered and uncovered) using different fish each time. An additional ten replicates per treatment were conducted to determine if there were any differences in cover selection in the presence of a predator model: a stuffed golden eagle (*Aquila chrysaetos*) with its wings spread, placed at the edge of the plywood cover. At 30 min, the predator was once moved by hand over the length of the tank and returned to its perch. Care was taken to avoid being seen by the fish during this operation. Observations were conducted only on sunny days between 1000 and 1600 h.

2.2. *Statistical analysis*

The SAS computer program (SAS Institute, 1990) was used for all statistical analyses, and a significance level of $P < 0.050$ was used for each test. For analysis of the fin length measurements, each length was scaled to body length (relative fin length = fin length/total body length $\times$ 100; Kindschi, 1987). The relative fin lengths were transformed (arcsine) prior to analysis of variance.

For analysis of the four-fish groups observed for cover preference, the 45 observations for each group were averaged and this mean was used in the non-parametric tests. For further analyses, the 45 observations were divided into three subsets of 0–15, 15–30, and 30–45 min. The Wilcoxon test was used to compare: (1) cover preference between fish from covered and uncovered raceways with the eagle present and without (separate tests); (2) cover preference within a treatment (covered/uncovered) between observations with the eagle present and without; (3) cover preference between the observations with and without the eagle present, combining covered and uncovered observations. Chi-square analysis was used in the behavioral tests to compare expected and observed cover preference. As the cover shaded one-third of the observation tank area, the fish would be located under cover one-third of the time (60 of 180 possible observations) based on a random distribution.

The categorical data of the HCP (eye, gill, pseudobranch, thymus, liver, kidney, spleen, gut, bile, fin, and opercle) were analyzed using chi-square maximum likelihood tests (Fienberg, 1980). Some categories were combined to reduce the number of zero cells in the frequency tables and to make the analysis more meaningful; the liver categories were reduced to two categories, normal or abnormal, and the 0 and 1 categories of bile color were combined. The blood parameters, length, weight, and condition factor were tested for normality with the Shapiro-Wilk statistic. Plasma protein, length, and condition factor proved to be normally distributed. These were analyzed separately for each date with an analysis of variance model. Mean comparisons for significant models were performed with Fisher's LSD test for each sampling period. Weight, hematocrit, leucocrit, and thymus, fat, bile, and fin index values of the HCP were rank transformed prior to analysis of variance within each sampling period.

3. Results

Light intensity measured in the shade of the uncovered raceways varied from 5610 to 6180 lx, or about 29.7–32.7% of full sunlight. Covered raceway light levels were 42.8 and

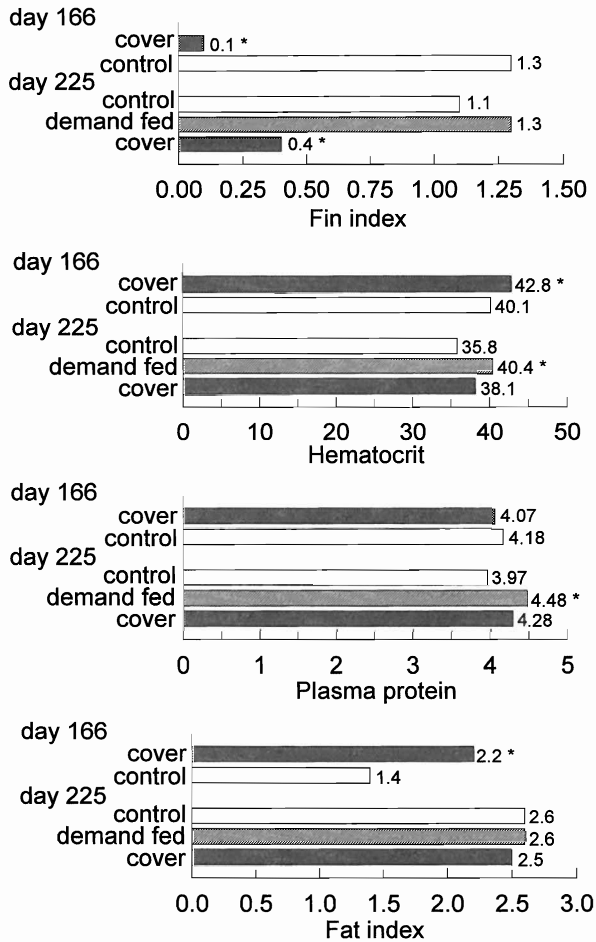

Fig. 1. Selected health and condition profile parameters from cutthroat trout sampled on Day 166 (prior to initiating demand feeding) and Day 225. An asterisk indicates the mean (replicates pooled, $n = 20$) is significantly different from the control.

72.0 lx, or 0.2-0.4% of full sunlight. The covers thus provided 77 to 131 times less light than uncovered raceways.

There were no significant differences in mean body weight at the end of the study among covered (67.4, 97.8 g), uncovered (73.9, 64.0 g), or demand-fed fish (64.8, 72.0 g). Feed conversion values (weight of feed fed/weight gain) ranged from 1.00 to 1.44 in each of the raceways and did not differ among treatments. Mortality ranged from 7 to 27% in each of the raceways, and was not significantly different among treatments.

Most HCP parameters were normal and did not differ among treatments. However, there were a few significant differences between fish reared in covered and uncovered raceways. Fat index values were significantly greater in fish from covered raceways than uncovered (2.2 vs. 1.4, respectively) during the first sample (Day 166; $P = 0.0001$; Fig. 1). However,

Table 1
Mean relative fin length (± s.d.) of cutthroat trout reared in covered and uncovered raceways after 166 and 225 days. The demand fed treatment was started on Day 168. A sample size of 20 was used for each mean except for the uncovered treatment, Day 166 ($n=40$). A common subscript letter among means in a given sampling day indicates no significant difference ($P \leq 0.05$). Means with no subscript are not significantly different

Fin	Day 166		Day 225		
	Cover	Uncovered	Cover	Uncovered	Demand fed
Dorsal	8.98	8.18	8.55	8.47	8.28
	(0.75)	(2.55)	(0.77)	(1.64)	(1.62)
Caudal	12.24	12.23	11.12	11.11	10.65
	(0.64)	(0.86)	(0.89)	(0.65)	(1.24)
Adipose	6.72	6.68	6.42	6.31	6.69
	(0.82)	(0.59)	(0.76)	(0.49)	(0.65)
Anal	10.19	10.72	10.67	10.88	10.65
	(1.06)	(2.08)	(0.59)	(0.56)	(0.55)
R. Pect.	10.25_a	8.01_b	8.70_a	8.09_{ab}	6.49_b
	(1.74)	(3.61)	(2.21)	(3.27)	(3.48)
L. Pect.	9.79_a	7.74_b	9.37_a	7.88_a	6.06_b
	(1.24)	(3.99)	(0.77)	(3.10)	(2.71)
R. Vent.	9.01_a	9.58_b	8.87	9.21	8.99
	(0.71)	(0.88)	(0.55)	(0.55)	(0.67)
L. Vent.	8.95_a	9.56_b	8.87	9.21	8.99
	(0.68)	(0.87)	(0.55)	(0.55)	(0.67)

by the end of the test, there were no differences in fat levels among any of the three treatments. Plasma protein values were not significantly different in the first sample, but on Day 225 the values were slightly but significantly higher ($P = 0.019$) in demand-fed fish than in hand-fed controls (4.48 and 3.97 g dl^{-1}, respectively; Fig. 1). Cover had no effect on plasma protein, but hematocrit was significantly higher in fish from covered raceways than uncovered both on Day 166 (42.8 and 40.1%; $P=0.0428$) and Day 225 (38.1 and 35.8%, respectively; $P = 0.0497$). Demand-fed fish also had significantly higher hematocrit values (40.4%) than hand-fed controls, but did not differ from covered fish (Fig. 1).

Covered raceways appeared noticeably cleaner when the covers were removed for monthly sampling. Histological preparations of gill samples from three fish from each

Table 2
Mean number of fish under cover, ± s.d. ($n=10$ four-fish groups), observed at 1 min intervals for 45 min in the presence of a potential predator or without

Minutes	Stuffed Eagle		Control	
	Covered	Uncovered	Covered	Uncovered
0–15	2.2 ± 0.91	2.6 ± 0.94	2.1 ± 0.96	2.2 ± 0.70
15–30	2.2 ± 0.92	2.6 ± 1.02	2.0 ± 1.12	2.5 ± 0.67
30–45	2.7 ± 0.87	3.0 ± 0.87	2.3 ± 1.09	2.9 ± 0.71
Total Period				
(0–45)	2.3 ± 1.05	2.7 ± 0.97	2.1 ± 1.06	2.5 ± 0.74

raceway were examined to see if the cleanliness had an impact on gill hyperplasia and hypertrophy. No difference was observed in cursory examination of photos taken from microscope slides.

Fin index values were significantly lower (better) in the covered raceways than uncovered ($P \leq 0.001$; Fig. 1) in both sampling periods. The difference was striking in the first sample where 95% of the fish from covered raceways had fins in excellent condition (0 category), whereas only 32% of the fish from uncovered raceways were in this category. Fin index values of fish from the demand-fed raceways did not differ from uncovered, hand-fed controls, but were significantly higher than values from covered raceways. Relative fin length data generally corroborated the fin index results, pinpointing the right and left pectoral fins as the fins which received significantly ($P < 0.03$) more wear in uncovered raceways (Table 1). Ventral fins were significantly ($P < 0.02$) shorter in the covered treatment in the first sample, but by Day 225 did not differ among treatments.

Preference for cover was significant (chi-square test, $P < 0.001$), although this preference did not differ between fish from covered and uncovered raceways. In the presence of the eagle, fish from covered raceways stayed under cover as frequently as uncovered fish during each of the 15 min periods and when all periods were pooled. Similarly, in tests without the eagle, there was no difference in cover preference between treatments (Table 2). There were no significant differences in cover use in the presence of a potential predator when statistical comparisons within a treatment were made for each 15 min segment and the 45 min period overall. When covered and uncovered treatments were combined, there was no significant difference in the cover preference between observations with the eagle present and without.

4. Discussion

4.1. Cover effects

Growth and general hatchery performance (feed conversion, mortality) of cutthroat trout were not significantly improved with the use of covered raceways. This result was also seen in a similar experiment with rainbow trout reared for 215 days under cover (Wagner and Bosakowski, 1994). Pickering et al. (1987) observed no difference in growth of rainbow and brown trout (*Salmo trutta*) after 5 months in circular tanks with 67% cover. However, Pickering et al. (1987) did note signs of chronic stress and reduced growth in Atlantic salmon (*Salmo salar*) without access to cover. Total darkness has been found to reduce growth in fish relative to those which experience normal photoperiods (Pyle, 1969). In this study, light levels reduced to 43 lx or less did not negatively affect growth.

The major benefit of cover was a reduction in fin erosion, primarily in the first half of the rearing period. Pectoral fins were significantly shorter in uncovered raceways. Fin erosion may result from fin nipping (Abbott and Dill, 1985), therefore a reduction in aggressive behavior might lead to healthier fins. Stringer and Hoar (1955) observed that fin nipping by Kamloops rainbow trout (*Oncorhynchus mykiss*) increased with increasing light up to about 26.9 lx, and above this there was a deceleration and a levelling of the number of nips at 43.0 lx (0.40% of full sunlight). Light levels under cover in this study were 42–72 lx, near or slightly above the nipping threshold. As the light measurements were made on a sunny day, it is reasonable to assume that on cloudy days, early morning, or late evening that light levels under cover may drop below the threshold level observed by Stringer and Hoar (1955). Fin condition of rainbow trout reared under cover did not differ from uncovered controls (Wagner and Bosakowski, 1994).

Higher hematocrit values were observed in cutthroat trout under cover. The difference between the means was slight ($<3\%$), and probably not biologically significant. Pickering et al. (1987) noted significant differences between covered and uncovered treatments in numbers of erythrocytes from rainbow trout, but not in brown trout or Atlantic salmon. The differences were inconsistent, with erythrocyte numbers in covered fish being significantly higher on two dates and significantly lower on another. Handling stress is known to increase hematocrit (Fletcher, 1975; Soivio and Oikari, 1976), and may be related to the differences observed.

There is evidence that rearing environment affects fish behaviors such as the 'startle reaction' to a visual stimulus (Roadhouse et al., 1986) and aggressiveness (Hoelzer, 1987; Olla et al., 1992). In the four-fish groups observed in this study, there was no difference in the preference for cover between fish reared in covered and uncovered raceways. In similar tests with rainbow trout (Wagner and Bosakowski, 1994) the only difference among the two treatments was for the initial 15 min period of the four-fish groups observed in the presence of the stuffed eagle. Fish from covered raceways selected cover more frequently in this case, but the lack of significant differences in the latter periods, or overall, suggested that the fish either habituated rapidly to the stuffed eagle or there was no real biological significance. The latter is more probable because the cutthroat trout used in this study are only one generation removed from the wild and would be expected to respond to a potential predator to a greater degree than a domesticated strain of rainbow trout. Vincent (1960) and Moyle (1969) both observed this phenomenon of greater fright response in wild vs. domesticated brook trout (*Salvelinus fontinalis*). This study indicated that rearing under cover does not alter cover preference behavior.

It was evident in both rainbow and cutthroat trout studies that fish still sought cover. Clearly, this innate survival behavior was present in these fish regardless of rearing method.

4.2. Demand feeders

Demand feeders have been widely used by the aquaculture industry in the last decade to reduce the labor required to feed fish, increase growth, and reduce feed conversion (Boydstun and Patterson, 1982; Tipping et al., 1986). Because fish can feed to satiation, use of demand feeders might also improve fin condition. Feeding to satiation has alleviated the fin erosion problem in some studies (Wolf, 1938; Larmoyeux and Piper, 1971). Kalleberg (1958) and Symons (1968) observed aggressive behavior associated with feeding, particularly when food was limiting.

In this study, the use of demand feeders did not eliminate or reduce fin erosion relative to fish that were hand-fed. The feeding regimen of four times per day for the controls may have had a significant impact, reducing the aggressiveness associated with hunger. Landless (1976) observed territorial behavior in rainbow trout where a single dominant individual would trigger the demand feeder rod. This indicates that aggressive behavior, and the subsequent fin erosion, is still a factor to consider in demand-fed systems. Further tests with fewer than four feedings per day in the control treatment may provide different results.

Demand-fed raceways had noticeably more algal growth and waste feed and feces than raceways fed by hand, requiring more frequent and thorough cleaning. In systems with higher flows (0.24–0.30 m s^{-1}; Burrows and Chenoweth, 1955), waste accumulation may not be a problem.

In conclusion, completely covered raceways appeared to produce a slight improvement in fin condition. The use of covers is recommended for cutthroat trout for early rearing if improved fin condition is desirable, but for larger fish the covers are impractical and provide little benefit. Covers may be useful for other species and for other specific situations, such as problems with sunburn or avian predators. Demand feeders did not affect hatchery performance, general health, or fin condition of cutthroat trout. Demand feeders may be useful for reducing labor without compromising hatchery performance, but were not useful for addressing fin erosion problems.

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