Hatchery Performance and Fin Erosion of Bonneville Cutthroat Trout, *Oncorhynchus clarki*, at Two Temperatures

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ABSTRACT. Bear Lake Bonneville strain cutthroat trout, *Oncorhynchus clarki utah*, were raised at two temperatures (13.4°C or 17.2°C) for 249 days in concrete raceways to determine if high rearing temperatures are a major mortality factor in culturing this species. Hatchery performance and general health were evaluated by necropsy-based health and condition profiles and by monitoring growth, mortality, and feed conversion. Mortality (<6%) was not significantly ($P > 0.05$) different between the two temperatures, but feed conversion was better at 13.4°C. Specific growth rate, final mean weight, mesenteric fat level, monthly temperature units per unit total length, and condition factor were significantly higher at the warmer water temperature. Fin erosion differences between fish at both temperatures were variable, with no clear temperature-related trend. A survey of 20 western U.S. hatcheries raising cutthroat trout was conducted to compare growth and mortality rates of several different strains at different temperatures; specific growth rates ranged from 0.65 at 8°C to 3.63 at 14.4°C. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworthpressinc.com]*

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INTRODUCTION

At the Glenwood State Fish Hatchery, Glenwood, Utah, higher-than-usual mortalities of cutthroat trout, *Oncorhynchus clarki utah*, raised concerns about possible detrimental conditions at that facility. Thorough water quality testing did not pinpoint any problems with heavy metals, dissolved oxygen, or other related variables. Disease diagnostic tests did not find any significant pathogens.

Temperatures at the Glenwood facility (14°C) are higher than those at other state hatcheries where cutthroat trout experience lower mortality, so temperature was suspected as a major contributor to mortality. To test this hypothesis, cutthroat trout were raised at the Utah Fisheries Experiment Station at two temperatures. Growth, mortality, and feed conversion were used to evaluate hatchery performance. Variables of the Health and Condition Profile (Goede and Barton 1990) were also monitored to indicate possible organ systems and general condition variables which might be adversely affected by temperature and contribute to mortality. Data from western hatcheries culturing cutthroat trout were also collected to provide additional information concerning the effect of temperature on mortality and growth rates of this species.

Potential differences in fin erosion at the two temperatures were also of interest in this study. Reash and Berra (1989) noted that fin erosion in fish from polluted sites was inversely correlated with water temperatures ranging from 2°C to 28°C. At a similar temperature range, Schneider and Nicholson (1980) also noted that the extent and severity of fin rot (active lesions present) increased as water temperatures dropped at two hatcheries growing Atlantic salmon, *Salmo salar*. Bosakowski and Wagner (1994) found no correlation between temperature and fin erosion, but that study was a survey and not a controlled experiment. In this study, the difference in the degree of fin erosion between two temperatures over a narrower water temperature range was evaluated in a controlled study.

MATERIALS AND METHODS

On 15 September 1995, 1,200 Bear Lake Bonneville strain cutthroat trout (mean weight = 1.3 g) were hand counted into each of six raceways (7.62 × 0.91 × 0.38 m, water volume). Three raceways were supplied with 13.4°C well water and three others with 17.2°C well water. Initial densities were 2827 fish/m^3 (3.73 kg/m^3 or a density index [Piper et al. 1986] of 0.69 kg/cm/m^3). The fish were fed a commercial pelleted diet for

249 days (Silvercup trout, Murray, Utah[1]). Feed for both treatments was initially hand fed 6 times/day at 2.8% of body weight. Because of the temperature differences, the same percent body weight could not be fed without wasting feed unnecessarily in the cold water treatment, possibly skewing feed conversion rates and efficiencies. Until the fish were large enough to switch to demand feeders, the rations were equalized based upon percentages of body weight recommended in dry-feed chart values (Piper et al. 1986) for each temperature. These percentages were adjusted, based upon observations of uneaten feed in the raceway to ensure the fish were being fed at or near satiation in both groups. For example on day 18, fish were fed 65% of chart values (Piper et al. 1986) in both treatments; this meant that fish raised at 13.4°C received 2.8% of body weight, but fish raised at 17.2°C received 3.7%, reflecting the increased demand for feed at the higher temperature. On day 32, the ration was reduced to 60% of chart (2.6% and 3.4% of body weight for cold and warm temperatures, respectively) and reduced to 55% on day 41 (2.37% and 3.14% body weight). On day 76, demand feeders were installed, one per raceway, and the fish fed *ad libitum* until the end of the experiment.

Initial water flow rate was 39 L/minute and was increased to 124 L/minute by the end of the study to maintain effluent dissolved oxygen levels of above 5 mg/L. Maximum density did not exceed 58.2 kg/m^3 (0.41 density index). Water quality of the hatchery well water measured by standard methods (APHA et al. 1989) was as follows: total alkalinity 222 mg/L as $CaCO_3$, total hardness 222 m/L as $CaCO_3$, pH 7.2, and total gas saturation 100 to 106%. Dissolved oxygen was monitored periodically with an oxygen meter calibrated with replicate Winkler titration tests. Dissolved oxygen did not drop below 5.0 mg/L except on one occasion when the low-head oxygen injection device in one raceway (17.4°C treatment) experienced a leak, which was promptly repaired. Total un-ionized ammonia nitrogen measured at the end of the study using the Nesslerization method (APHA et al. 1989) did not exceed 0.017 mg/L.

Mean fish weight was determined for each raceway at the end of each month by averaging five dip-netted samples taken from fish crowded to the head of the raceway. Feed conversion was calculated for fish in each raceway by dividing the total weight of feed fed by the total weight gain during the experiment. Monthly temperature units per cm growth (TU/cm) were calculated as TU/cm = (mean water temperature [°C] × 249/30) divided by the increase in length (cm) during the experiment. Lengths were derived from mean weight and condition factor data collected in the necropsies, using the following formula: condition factor = (weight in g)/

1. Use of trade or manufacturer's name does not imply endorsement.

(length in mm)^3 × 10^5. Specific growth rates were calculated using the formula SGR = 100 × ($\log_e$ [final weight] − $\log_e$ [initial weight])/(culture period in days).

Health and Condition Profiles (HCP; Goede and Barton 1990) were conducted on experiment days 138, 199, and 248, using 10 fish per raceway. Fish were killed by a lethal dose of MS-222 (tricaine methanesulfonate), and all fish were examined by the same observer. To prevent observer bias, the observer was aided by an assistant and was not aware of the treatment from which fish were sampled until after all examinations were completed. HCP fin index values were modified so that the values ranged from 0 (no erosion) to 2 (severe erosion), and fin length was part of the decision criteria in addition to hemorrhaging and other tissue degradation signs used by Goede and Barton (1990) to rank fin erosion. On the same dates and using the same fish, maximum fin length was measured on each fin, except the adipose fin, and scaled to total body length: fin length (mm)/total length (mm) × 100 (Kindschi 1987).

To compare the results of our temperature tests with other facilities, a survey was mailed to 20 hatcheries culturing cutthroat trout of various subspecies. The survey requested data on a given lot of fish monitored through one production cycle. Data requested included mortality rates, strain, temperature, initial and final weight, culture period, feeding method and frequency, diet type, final density and water flow, and other relevant comments for each lot. Due to some inconsistencies in the way the data were reported, some of these variables are not summarized in this report.

Mortality was arc-sine transformed and analyzed with a *t*-test. Bile, fat, fin, and gut indices; leucocrit, opercle and fin length data were not normally distributed (Kolmogorov-Smirnov test), so were rank-transformed and analyzed by Student's *t*-test separately for each sampling date (SPSS 1993). Categorical variables of the HCP were analyzed by chi-square analysis separately for each sampling date. Total length, mean weight, specific growth rate, feed conversion, TU/cm, hematocrit, and plasma protein were normally distributed and analyzed with *t*-tests for independent samples. A significance level of $P \leq 0.05$ was used for all tests.

RESULTS

Mortality was relatively low (<6%) over the 249-day study and was not significantly different between the two temperatures. Feed conversion rates were significantly more efficient at 13.4°C than at 17.2°C (Table 1). As expected, specific growth rate, final mean weight per fish, and condition factor were significantly higher at the warmer water temperature

(Table 1). The higher temperature also resulted in significantly higher mesenteric fat levels in each of the three sampling periods (Table 2). Monthly temperature units per cm of growth were significantly higher at the higher temperature (9.25 ± 0.42 TU/cm) than at the lower temperature (7.05 ± 0.41 TU/cm; $P \leq 0.003$).

Some additional HCP variables were influenced by temperature (Table 2). Bile index values were significantly higher at 17.2°C, possibly due to the more rapid oxidation of the bilirubin to biliverdin, which is indicated by the color changes noted in the HCP (Goede and Barton 1990). Hematocrit values were significantly greater at the colder temperature in all three samples. Differences in leucocrit and plasma protein were also noted but were variable over time. Leucocrit was significantly higher ($P \leq 0.004$) in fish at the warmer temperature in the first sample but not in the others. Plasma protein was significantly higher at 17.2°C in the second sample ($P \leq 0.017$), but in the third sample the reverse was true ($P \leq 0.006$). There were no significant differences in gut or fin index values; nor in liver, psuedobranch, kidney, gill, eye, or opercle categories.

Fin length was significantly greater at the colder temperature for caudal ($P \leq 0.002$) and dorsal fins ($P \leq 0.02$). In contrast, the left pectoral fin was significantly shorter in the last sample in the colder water (Table 2). The other fins did not differ between the temperature treatments.

Fifteen out-of-state hatcheries and five in-state hatcheries responded to the survey, which is summarized in Table 3. Fish mortality experienced at these hatcheries averaged 16.3% and ranged from 2 to 91%. Some hatcheries included egg mortality in the total, so direct comparisons among strains or temperatures were compromised. Specific growth rates ranged from 0.65 at 8°C to 3.63 at 14.4°C and averaged 1.85 over all lots and hatcheries. Average temperatures at the hatcheries ranged from 8°C to

TABLE 1. Hatchery performance of Bonneville cutthroat trout cultured at either 13.4°C or 17.2°C for 249 days. An asterisk indicates a significant difference between temperatures ($P \leq 0.05$).

	13.4°C	17.2°C
Mortality (%)	3.5	5.2
Specific growth rate	1.64	1.74*
Final mean weight (g)	78.7	99.7*
Final mean length (mm)	201	213
Final condition factor	0.9253	0.9953*

TABLE 2. Summary of relative fin length (100 × fin length/total length) and health and condition profile (HCP) results for cutthroat trout cultured at either 13.4°C or 17.2°C and sampled on three dates. An asterisk indicates a significant difference ($P \leq 0.05$) between temperature treatments for a given date.

	Sampling day					
	138		199		248	
	13.4°C	17.2°C	13.4°C	17.2°C	13.4°C	17.2°C
HCP variables						
Plasma protein (g/dL)	3.9	4.1	3.8*	4.3	4.8*	5.3
Hematocrit (%)	41*	36	42*	39	42*	40
Leucocrit (%)	1.0*	1.4	1.2	1.2	1.2	1.1
Fat index	1.9*	2.6	1.4*	2.8	2.4*	2.9
Fin index	0.4	0.5	0.6	0.4	0.6	0.5
Bile index	0.2*	0.5	0.2*	1.0	0.5*	0.9
Relative fin length (%)						
Dorsal	10.0	9.8	9.5*	8.8	9.4*	8.8
Caudal	13.0	11.8	11.8	11.1	11.1	10.4
Anal	10.3	10.3	10.1	10.3	10.1	10.0
Right pectoral	9.6	9.7	9.2	8.7	8.7	9.5
Left pectoral	10.1	9.2	8.8	9.1	7.5*	8.8
Right ventral	10.2	9.9	9.6	9.8	9.4	9.4
Left ventral	10.2	9.8	9.7	9.9	9.4	9.5

16°C, with some hatcheries that used river water experiencing even higher values in the summer. Simple least-squares regression of specific growth rate and temperature indicated that the relationship was poor for this set of data ($r^2 = 0.0009$, $P > 0.05$). The correlation between mortality and temperature was equally weak ($r^2 = 0.012$, $P > 0.05$).

The 20 hatcheries surveyed varied substantially in husbandry practices. The source of cutthroat trout eggs in the majority of hatcheries was wild broodstock, but three hatcheries received eggs from domesticated broodstocks. Six hatcheries fed a commercial salmon diet, and five used truck blowers, auto-feeders, or demand feeders in addition to, or instead of, hand feeding. Four hatcheries used floating feeds.

TABLE 3. Comparisons of growth and mortality among hatcheries in the western U.S. producing cutthroat trout. Some hatcheries are represented by more than one lot of fish.

Strain	Temperature (°C)	Mortality (%)	Initial weight (g)	Final weight (g)	Culture period (days)	SGR (%/day)
Bear Lake	8.3	12	0.19	15.9	288	1.53
	8.3	6	0.18	37.8	333	1.60
	14.4	23	0.07	39.6	281	2.27
	13.9	22	0.18	38.7	279	1.93
	13.9	16	0.16	9.4	315	1.29
	14.4	5	0.16	6.2	401	0.91
	14.4	2	0.16	6.7	103	3.63
	11.1	10	0.13	32.9	320	1.73
	11.1	3	0.13	41.2	303	1.90
	7.8-8.3	2	0.11	71.1	319	2.03
	7.7-8.3	10	0.02	21.6	393	1.83
	2.8-13.3	27	0.34	20.6	304	1.35
Coastal	0.6-21.1		0.16	113.4	454	1.45
	5.6-12.2	2	64.80	98.6	65	0.65
Colorado River	7.7-8.3	15	0.11	113.0	407	1.70
	10.6	91	0.70	0.6	109	1.97
	14.4	9	0.08	226.8	730	1.09
Independence	10.6	48	0.16	283.5	736	1.02
	10.6	7	8.25	78.2	207	1.09
Lahontan	10.0	5	0.15	2.6	100	2.85
	9.4	3	0.10	22.7	321	1.70
Snake River	11.4-17.0	22	0.09	28.0	345	1.66
	3.8-19.6	19	0.12	22.7	201	2.61
	10.8-17.0	25	1.74	110.6	343	1.21
	10.0-11.1	6	0.14	87.2	262	2.46
	5.6-13.3	25	0.10	6.0	121	3.38
	8.9	20	0.10	2.5	152	2.10
	14.4	6	0.11	22.7	170	2.15
	15.6	13	15.12	129.6	152	1.41
	9.4	4	0.09	4.5	120	3.30
Strawberry	11.1-12.2	21	0.09	44.5	289	2.15
West Slope	10.0	27	0.07	2.5	180	1.99
Yellowstone	3.2-17.8	27	0.09	41.2	426	1.44
	5.7-17.8	6	0.10	75.6	464	1.44

DISCUSSION

Growth in this study was significantly faster at the warmer water temperature (specific growth rate of 1.74 vs. 1.64), although feed was not converted as efficiently (feed conversion of 1.16 vs. 0.95). Temperature units per centimeter of growth also reflected the poorer growth efficiency at the higher temperature (9.25 vs. 7.05 TU/cm). Compromised growth efficiencies at higher temperatures have been observed for Atlantic salmon (Dwyer and Piper 1987), brook trout, *Salvelinus fontinalis* (Dwyer et al. 1983), and other salmonids tested at the U.S. Fish and Wildlife Service Fish Technology Center, Bozeman, Montana. However, Banks et al. (1971) did not observe any differences in the feed conversion of chinook salmon, *O. tshawytscha*, fingerlings grown at temperatures ranging from 10.0°C to 18.3°C. The specific growth rates of cutthroat trout in this study were comparable to those observed by the other hatcheries surveyed and those in previous studies (Wagner et al. 1997). Compared to hatchery fish, wild greenback cutthroat trout, *O. clarki stomias*, and Colorado River cutthroat trout, *O. c. pleuriticus*, sampled from headwater streams had specific growth rates that were ten to a hundredfold less (Scarnecchia and Bergersen 1986). Moore and Gregory (1988) reported growth rates ranging from 0.27 to 1.15 in Mack Creek, Oregon. Platts (1958) reported a 233-g increase in average weight from age 1 to age 2 cutthroat trout in Strawberry Reservoir, Utah, which is a SGR of about 0.315 assuming a 365 day interval.

Higher condition factors (0.995 vs. 0.925) and fat levels (2.9 vs. 2.4) were observed in this study at the higher temperature. The increased lipid levels at the higher temperature are probably due to higher apparent absorbability of lipids in the diet (Atherton and Aitken 1970; Andrews et al. 1978). Condition factor has also been reported to increase with temperature in brook trout (Dwyer et al. 1983) and Atlantic salmon (Dwyer and Piper 1987), but not in chinook salmon (Banks et al. 1971).

Fin erosion in the present study was generally not affected, or inconsistently affected, by temperature. Similarly, Bosakowski and Wagner (1994) found that temperature was not correlated with fin erosion in a survey of state hatcheries. Apparently, the effects of temperature on fin erosion are noticeable only over a wider range of temperature, where temperatures closer to the extremes of tolerance result in greater fin erosion (Schneider and Nicholson 1980; Reash and Berra 1989). For example with turbot, *Scophthalmus maximus*, Devesa et al. (1989) noted that epizootics of ulcerative fin lesions inhabited by myxobacteria, *Vibrio*, and ciliate protozoans resembling *Cryptocaryon* were associated with temperatures above 20°C. Decreases in immunological competence at temperature extremes

have been reported (Finn and Nielsen 1971; Dunn et al. 1989; Bly and Clem 1991) and may partially explain the increase in fin erosion.

In this study, hematocrit was significantly higher at colder temperatures, contrary to Banks et al. (1971), who noted a positive corrrelation between hemoglobin concentrations and temperature. DeWilde and Houston (1967) noted that rainbow trout grown at 3°C and 7°C had lower erythrocyte counts, hematocrit, and hemoglobin than did fish at 11°C, 14°C, and 17°C. However, Lochmiller et al. (1989) noted that striped bass, *Morone saxatilis*, had significantly higher hematocrit and hemoglobin levels in winter than in summer. These effects may be related to other factors related to season rather than temperature per se. For example, Tun and Houston (1986) have observed hematocrit and hemoglobin increases associated with shortened day length as well as increased temperature (5°C, 20°C) and hypoxia. Given the negative effect of elevated temperature on oxygen solubility, production of additional oxygen-carrying capacity by increased hemoglobin and hematocrit would be an expected adaptative response. Plasma protein differences were variable in this study, but values were within the normal ranges reported for rainbow trout (Wedemeyer and Chatterton 1970). Dwyer et al. (1982) noted that serum protein and hematocrit increased with temperature in steelhead, *O. mykiss*. Dwyer et al. (1981a) did not observe any differences in hematocrit, leucocrit, or plasma protein in lake trout, *Salvelinus namaycush*, until temperatures reached 19°C. In rainbow trout, *O. mykiss*, Dwyer et al. (1981b) observed no trends in hematocrit, serum protein, or leucocrit at temperatures ranging from 4°C to 19°C.

Survey results indicated that cutthroat trout are successfully being grown at average temperatures ranging from 8°C to 16°C, and there was no correlation between temperatures in this range and mortality. The survey also indicated that specific growth rates ranging from 0.65 to 3.63 can be expected for cutthroat trout, with particular values dependent upon temperature, strain, and culture methods.

In summary, survey results and results of the temperature tests indicated that rearing of cutthroat trout at temperatures of 8°C to 17°C was possible without temperature-related mortality. Higher temperature resulted in faster growth rates and higher fat levels, but fin erosion was generally unaffected. Hopefully the survey data and test results will provide a benchmark and a stimulus for further improvements in cutthroat trout growth rates and reductions in average mortality.

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