COMPARISON OF HEAT TOLERANCES OF REDBAND TROUT, FIREHOLE RIVER RAINBOW TROUT AND WYTHEVILLE RAINBOW TROUT

by

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ABSTRACT

Redband trout Salmo sp. ($\bar{X}$ TL = 237 mm), Firehole River rainbow trout S. gairdneri ($\bar{X}$ TL - 90 mm) and Wytheville rainbow trout, a domesticated strain ($\bar{X}$ TL = 258 mm) were acclimated to 15, 20 and 23 C and then subjected to temperature increases of 0.5 C/day until death. Lethal temperature ranges were 25.8 - 27.1, 25.6 - 27.8, and 26.4 - 27.7 C for the three trout, respectively. Upper lethal temperatures (LT_{50}) were also determined for each trout. Firehole River rainbow trout acclimated to 20 C died at a faster rate than at other acclimation temperatures. The other trout died at similar rates among acclimation temperatures.

Rainbow trout Salmo gairdneri stocked annually into put-and-take trout fisheries in Texas are progeny of the domesticated Wytheville strain. This trout is discussed in Kincaid (1981). Texas summer water temperatures commonly exceed the highest temperature (24.0 C) suggested by Hokanson et al. (1977) for short-term survival of rainbow trout. Survival of Wytheville trout is low because water temperatures approach 27 C (White 1968). Domesticated rainbow trout have upper incipient lethal temperatures (Fry et al. 1946) of 23.7 - 26.2 (Kaya 1978; Vancil et al. 1979; Bidgood 1980).

In an effort to expand existing trout fisheries and the fishing season, Texas biologists are evaluating the ability of two reportedly warm-water trout to oversummer. They are the Firehole River rainbow trout from the Firehole River, Wyoming and redband trout Salmo sp. from Parsnip Reservoir, Oregon. Other investigators have reported the upper incipient lethal temperatures for the Firehole River rainbow trout are 25.0 - 26.2 C (Kaya 1978) and upper lethal temperatures (Otto and Rice 1977), LT_{50}, for redband trout are 26.8 - 27.4 C (Sonski 1982). These studies were conducted under different conditions and experimental methods, thus making direct comparisons of results difficult. This study compares the upper lethal temperatures of redband trout, and Firehole River and Wytheville rainbow trout under the same experimental design.

METHODS

Redband trout were obtained from the Fish Cultural Development Center, Bozeman, Montana. These fish were spawned (May 1980) from wild stock captured in Parsnip Reservoir, Oregon. In August 1981, live fish were air-freighted to Heart of the Hills Research Station, Ingram, Texas where they were maintained indoors at 14-21 C for 11 months prior to temperature acclimation. Firehole River rainbow trout juveniles were produced at this station from adult fish collected from the Firehole River. They were held at 16 - 21 C indoors for 9 months before temperature acclimation. Wytheville rainbow trout were obtained from the San Marcos State Fish Hatchery, Texas. These fish were part of stock used in Texas trout fisheries, acquired through Norfork National Fish Hatchery, Arkansas. Fish were transported to Heart of the Hills Research Station by truck in March 1982 and maintained at 18 - 21 C for 8 months prior to temperature acclimation.

During all sequences of the experiment fishes were fed commercial production trout pellets (38% crude protein, 5% fat) according to the feeding table recommended by Sterling H. Nelson and Sons, Murray, Utah. During a 14-day period prior to temperature acclimation all fish were held at 18 C, and an antibiotic was added to their feed (oxytetracycline, 2.5 g/45 kg fish/day). This medication was administered to prevent an infestation of Aeromonas hydrophila. This bacteria had been identified (R. Jones, United States Fish and Wildlife Service, Pinetop, Arizona, personal communication) earlier on some redband trout cultured at this station. The fishes used in the experiment did not display clinical signs of the disease.

Three cylindrical 800-liter fiberglass tanks (diameter = 91.4 cm) served as temperature acclimation-control tanks. Redband trout and Wytheville rainbow trout were held in the main section of each tank; because of their smaller size (Table 1), Firehole River rainbow trout were held in wire baskets (320 x 350 x 150 mm, 6-mm mesh) that were partially submerged and attached to the inside wall of each tank.

Tank temperatures were adjusted from 18 C to acclimation temperatures of 15, 20 and 23 C at a rate of 1.0 C/day. Fish were held at acclimation temperatures for 21 days before placement into the test tank. Temperatures in all tanks were regulated by thermostatically controlled cooling or heating units accurate to $\pm$ 0.1 C. Air was supplied to all tanks to mix heated or cooled water. Water passed through gravel and rock filters and feces that accumulated on the bottom of tanks were removed daily.

Testing took place in one tank. This tank was divided with netted frames into three compartments. The electrical system used to produce constant temperature increases was modified from Abell et al. (1977) and consisted of electrically timed, gear-driven thermoregulators which controlled heating elements.

Fishes of each acclimation temperature group were randomly assigned to a compartment. As the water temperature in the test tank reached an acclimation temperature the respective group of fishes (Table 1) were placed in their compartment. Water temperature was increased 0.5 C/day until all fish died. Fishes remaining in the acclimation tanks served as controls.

The temperature was recorded when a species within a compartment stopped feeding and when individual deaths occurred. Fish were considered dead when they lacked opercular movement and did not respond to touch (Otto and Rice 1977).

Mortality data were analyzed for each acclimation temperature group. Percentage cumulative mortalities (arcsin transformation) were regressed on lethal temperatures to determine LT_{50}'s, temperatures when 50% mortality occurred. The effect of acclimation temperature on heat tolerance was determined by quantifying differences in regression line elevation (height of the Y-intercept) and slope (death rate) using analysis of covariance (Snedecor and Cochran 1978). Differences in elevation were not tested where significant differences in slope were indicated. Size of fishes restricted analysis to the within species classification.

RESULTS AND DISCUSSION

There were little differences in temperatures at which each trout strain stopped feeding. Some fish of each strain first stopped feeding at 25.0 C; no redband trout or Wytheville rainbow trout continued to feed at temperatures greater than 26.0 C. Firehole River rainbow trout fed up to 26.7 C. Embody (1927) reported negligible feeding by rainbow trout in water greater than 25.0 C. Sonski (1982) noted that juvenile redband trout ($\bar{X}$ TL = 130 mm) stopped feeding at 25.5 - 27.0 C. Redband trout and Firehole River rainbow trout feed in their native habitat at temperatures exceeding 28.0 (Kaeding and Kaya 1978; Behnke 1979).

One control mortality was recorded for each species held at the 23-C acclimation temperature. Fishes were probably heat stressed during the experiment and acclimation period. Mortality of redband trout held at 23 C has been previously reported by Sonski (1982; 1983).

There were little differences in lethal temperatures and LT_{50}'s between acclimation temperatures within redband trout and Wytheville rainbow trout (Table 2). Comparison of regression lines for these trout indicated there were no significant differences in slopes or elevations (Table 3). Significant differences did exist, however, between slopes for Firehole River rainbow trout (Table 3); fish acclimated to 20 C died at a faster rate (Table 2).

Firehole River rainbow trout acclimated to 15 C exhibited the highest degree of heat tolerance of all species and acclimation temperatures tested (Table 2). Similarly, Kaya (1978) determined Firehole River rainbow trout acclimated to 13.0 C and 17.0 C had higher upper incipient lethal temperatures than domestic strain (Winthrop) rainbow trout acclimated to the same temperatures. Additional studies indicated redband trout (Sonski 1982), rainbow trout (Vancil et al. 1979) and other salmonids (Fry et al. 1946; Brett 1952) acclimated to warmer temperatures were more heat tolerant than those acclimated to cooler temperatures.

There were differences in heat tolerance for fishes of similar size. The Wytheville rainbow trout had LT_{50}'s 0.6 to 0.8 C higher than those for redband trout (Table 2). Experimental data is not available to compare heat tolerance of Firehole River rainbow trout in this size classification; however, LT_{50}'s determined for 130-mm TL redband trout (Sonski 1982) were similar to LT_{50}'s for fingerling Firehole River rainbow trout.

Fish size may influence results of heat tolerance determinations. Redband trout juveniles (130 mm TL) tested under identical conditions (Sonski 1982) had higher LT_{50} values than determined in this experiment with larger fish. Similarly, data compiled by Hokanson (1977) implies juvenile rainbow trout had higher upper incipient lethal temperatures (25.0 - 26.5 C) than adults (21.0 C). However, Bidgood (1980) found no differences in heat resistance of rainbow trout between five age groups (35 - 107 mm) acclimated to 10.0 C.

Agreement exists between this study and the findings of Kaya (1978) for Firehole River rainbow trout. This species does not exhibit exceptionally higher heat tolerance than domestic strain rainbow trout. These findings are supported by the genetic work of Fisher et al. (1982) who determined that Firehole River rainbow trout were not genetically different from hatchery strains.

Firehole River rainbow trout and redband trout have been reported to survive at water temperatures (Kaeding and Kaya 1978; Kaya 1978; Behnke 1979) well above the lethal temperatures found in this experiment. These trout may survive lethal exposure for prolonged time periods by behavorial adaptations to the environment such as seeking thermal refugia or shifting reproductive season to avoid detrimental effects on eggs and young (Kaya 1977; Kaya et al. 1977; Fisher et al. 1982). Also, Dickson and Kramer (1971) suggested wild rainbow trout are more active than domestic strain rainbow trout at high temperatures. This allows more available energy for swimming (Brett 1964).

Results of this experiment demonstrate a conflict between the experimental heat tolerance of Firehole River rainbow trout and redband trout and survival of these trouts at higher temperatures in native habitats. To resolve the discrepancy field trials are recommended. Redband trout have been selected to be introduced into candidate waters because they are available from Federal hatcheries. Fishery management surveys to determine angler acceptance and oversummer survival will identify if there are additional benefits in stocking redband trout than stocking domesticated rainbow trout into Texas trout fisheries.

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Table 1. Vital characteristics and number of three trout strains used in heat tolerance experiments at Heart of the Hills Research Station, Ingram, Texas, 1982. All length measurements are total length; SD is the standard deviation of means.

Strain	Age (month)	Length (mm) mean	Length (mm) SD	Weight (g) mean	Weight (g) SD	Numbers of fish experimental[a]	Numbers of fish control
Redband trout	25	236.7	34.9	141.0	62.5	5	5
Firehole River rainbow trout	9	90.0	9.8	19.0	6.4	6	5
Wytheville rainbow trout	26	257.5	14.2	199.7	31.0	5	5

[a] Number of fish subjected to temperature increases for each acclimation temperature (15, 20 and 23 C).

Table 2. Upper lethal temperatures and regressions for three trout strains exposed to temperature increases of 0.5 C/day at Heart of the Hills Research Station, Ingram, Texas, 1982.

Strain	Acclimation temperature (C)	Lethal temperature range (C)	LT_{50} (C)	Slope[a]	Intercept[a]	r^2
Redband trout	15	25.8 - 26.8	26.2	50.37	-1,276.80	0.728
	20	25.8 - 27.1	26.2	45.80	-1,155.18	0.957
	23	25.8 - 27.1	26.2	45.80	-1,155.18	0.957
Firehole River rainbow trout	15	27.2 - 27.8	27.4	103.41	-2,788.42	0.975
	20	27.2 - 27.4	27.2	273.80	-7,411.03	0.995
	23	25.6 - 27.3	26.3	30.75	-763.62	0.823
Wytheville rainbow trout	15	26.8 - 27.7	27.0	66.72	-1,756.84	0.922
	20	26.4 - 27.3	26.8	61.92	-1,614.56	0.829
	23	26.8 - 27.7	27.0	69.76	-1,838.80	0.976

[a] Slope and intercept were obtained from regression equation expressed by arcsin $\underline{Y} = \underline{a} + \underline{bX}$ where $\underline{a}$ = $\underline{Y}$-intercept at $\underline{X}$ = 0, $\underline{b}$ = slope, and $\underline{X}$ = lethal temperature.

Table 3. Tests of significance from analysis of covariance for heat tolerance tests of three trout strains conducted at Heart of the Hills Research Station, Ingram, Texas, 1982. Regression lines were compared for each strain acclimated to three temperatures.

Strain	Slope		Elevation	
	F	df[b]	*F*	df
Redband trout	0.03	2,4	0.02	2,6
Firehole River rainbow trout	5.79[a]	2,5	-[c]	-
Wytheville rainbow trout	0.06	2,5	2.34	2,7

[a] Indicates a significant *F*-value at $\alpha = 0.05$.

[b] Degrees of freedom (df) referring to numerator df, denominator df used to determine critical (table) *F*-values.

[c] Significance test not performed when differences in slope were determined.