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Final Report

Upper Temperature Tolerance of Juvenile and Adult Brown and Rainbow Trout Tested Under Flowing Conditions

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September, 1997

This study was funded in part by the Federal Aid in Sport Fish Restoration Act under Project F-26, Georgia

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Final Report

State: Georgia | Project Number: F-26

Project Title: Walton Experiment Station

Project Type: Research and Survey

Study XXV Title: Upper Temperature Tolerance of Juvenile and Adult Brown and Rainbow Trout Tested Under Flowing Conditions

Period Covered: 1 July 1992 - 30 June 1997

Study Objective: To review the literature for recommended criteria and to conduct laboratory experiments to determine the temperature tolerance of juvenile and adult brown and rainbow trout for the development of protective temperature criteria.

Abstract

The upper temperature tolerance of juvenile and adult Walhalla strain brown (*Salmo trutta*) and Erwin strain rainbow trout (*Oncorhynchus mykiss*) was determined. The tolerance tests were designed to simulate in situ conditions for trout in the Chattahoochee River, Atlanta, Georgia, as closely as possible. The test protocols included using Chattahoochee River water, testing the fish under a flow rate of 15 cm per second, 20°C acclimation temperature, a water temperature increase of 0.008°C/min, 14:10 light:dark photo period, and test temperatures of 24, 26, 27, and 29°C. Adult brown trout had the highest tolerance of all the trout tested. Juvenile brown trout were the second most tolerant, except at 24°C where they were the least tolerant. Adult rainbow trout were the third most tolerant, except at 27°C where juvenile rainbow trout were third. The order of tolerance from most tolerant to least at 29°C, expressed as the median temperature at which equilibrium was lost, was adult brown trout, juvenile brown trout, adult rainbow trout, and juvenile rainbow trout.

Introduction

Maintaining acceptable water temperatures for trout below hydropower projects with hypolimnetic releases in historically warmwater stream systems can be difficult. This is doubly true in a rapidly developing metropolitan area. Hypolimnetic releases from Buford Dam on the Chattahoochee River provide a thermal regime suitable for trout. This fishery is within metropolitan Atlanta, Georgia (Figure 1). Native warmwater fish no longer maintain a significant fishery in this 77km river segment because of the altered thermal regime. The State of Georgia has stocked trout in this tailwater since 1960. The lower 19km of trout water is separated from the upper 58km by Morgan Falls Dam, a run-of-the-river hydropower facility that impounds very little water. This lower tailwater is managed as a put-grow-and-take fishery with annual stockings of 75mm brown (*Salmo trutta*) and 150mm rainbow trout (*Oncorhynchus mykiss*). The upper tailwater is managed as a put-and-take trout fishery by stocking 230mm brown and rainbow trout weekly from March through September.

Hydropower discharge patterns at Buford Dam typically follow a pattern of power generation releases during the weekdays and minimum flow releases during the weekends. Low flow weekend releases provide anglers the opportunity to fish the river. However, a heavy summer rain over the weekend can result in significant warmwater inflow and high water temperatures below Morgan Falls Dam. Such warm water events may be exacerbated by increasing impervious surface coverage within warmwater stream tributaries associated with urbanization and point source

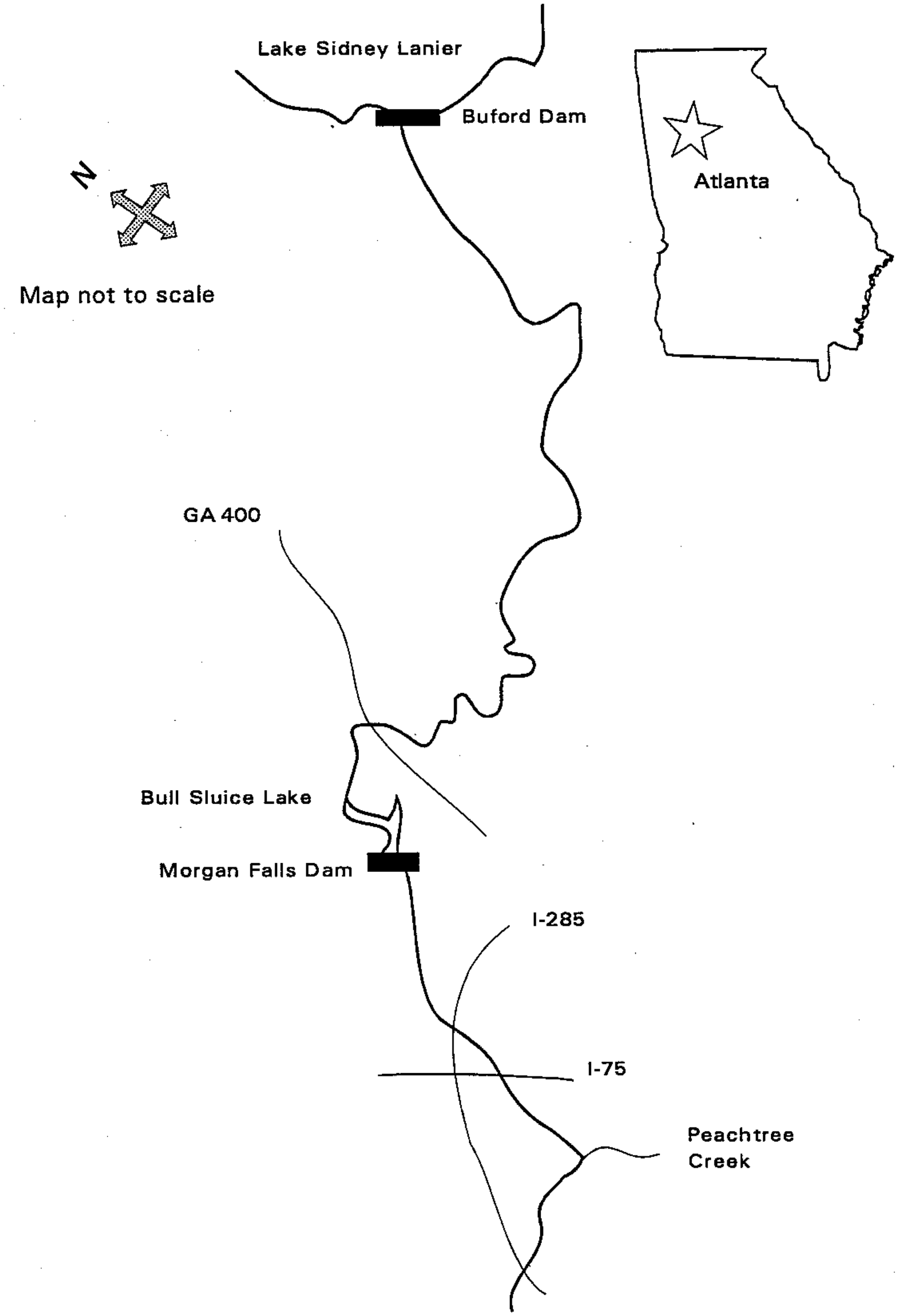

Figure 1. Area map of Chattahoochee River tailwater trout fisheries, Atlanta, Georgia.

discharges. Temperatures as high as 27.5°C have been documented in the Chattahoochee River trout waters below Morgan Falls Dam (Biagi and Martin 1992). Warm water events (≥23°C) are generally of short duration and their effects on the fishery are mostly unknown. Research has shown that temperatures above 23°C are particularly detrimental to trout fisheries (Elliott 1975[a], Elliott 1975[b], Elliott 1975[c], Cherry et al. 1977, Hokanson et al. 1977, Hartzler et al. 1990). The 27.5°C experienced in this section of river during 1989 resulted in the loss of all trout <254mm in length (Biagi and Martin 1992).

Georgia water quality regulations (Georgia Water Quality Control Board 1967) specified no allowable increase in trout stream temperatures before amendments were made in 1976. These amendments were developed out of a perceived need to allow for some development (primarily low-head dams) on lesser quality streams (McIntyre 1976). Separate regulations were established for primary trout streams (streams with natural trout reproduction) and secondary trout streams (those without natural reproduction, but capable of supporting trout year around). Regulations established for primary trout streams allow no temperature elevation above the ambient thermal regime. Regulations for secondary trout waters allow a maximum temperature elevation of 2°F (1.1°C) above ambient.

The language of the regulations for secondary trout waters is ambiguous about whether it applies to the trout stream as a whole or if it applies to each individual permitted discharge. The latter interpretation could theoretically allow cumulative temperature increases in a trout stream that exceed desirable limits. This would significantly reduce or eliminate summertime trout habitat in many streams. Because of this ambiguity, the current standard for secondary trout streams is difficult to apply and does not address the many non-point sources resulting from current development trends along the Chattahoochee River corridor. Defining sound protective standards for large multiple use streams like the Chattahoochee River tailwater is critical so potential impacts can be anticipated and avoided through appropriate regulatory means.

Regulatory officials have requested guidance on how long trout can tolerate high temperatures so they can develop protective standards for the Chattahoochee River. Existing temperature tolerance literature does not provide clear-cut answers for the Buford Dam tailrace. Tests for evaluating acceptable thermal regimes for fish include bioassays to determine such things as preferred temperature, optimal growth temperature, lethal temperature, incipient upper lethal temperatures, upper ultimate lethal temperature, critical thermal maxima (CTM), and critical swim speeds (Brown 1946, Bishai 1960, Cox 1974, Jobling 1981, Schneider and Conners 1982). Results of such research varies among and between the studies reviewed. For instance, Bidgood and Berst (1969) estimated the upper incipient lethal temperature for rainbow trout to be between 25 and 26°C while Soldwedel and Pyle (1967) reported rainbow trout survived exposure to 30.6°C.

Coutant (1977), Jobling (1981), Raleigh et al. (1986), and Armour (1994) provide literature reviews on optimum growth, final preference, avoidance and lethal temperature for brown and rainbow trout. Brown and rainbow trout growth occurs from 3.9 to 19.5°C (Elliott 1975b, Hokanson et al. 1977). Optimal or maximized growth occurs within 10 -18.9°C depending on acclimation temperature, strain, or confounding water quality parameters (Elliot 1975a, Hokanson et al. 1977). The upper ultimate lethal temperature for rainbow trout was reported as 25.6°C and 27°C (Hokanson et al. 1977, Vancil et al. 1979), while Soldwedel and Pyle (1967) found rainbow trout in ponds survived summertime water temperatures as high as 84.5°F (29.2°C) during field tests. Cherry et al. (1977) found the 7-day upper lethal temperature to be 25°C for rainbow trout and 23°C for brown trout.

Laboratory tests referenced in the literature generally do not represent thermal conditions found in the Chattahoochee River. Fish tested under the referenced test protocols were subjected to instant temperature changes as the fish were moved from an acclimation tank to the warm water test tank. Although size and strain of test fish vary, fry or juvenile fish are the typical size tested. Some research has shown that fry have a higher temperature tolerance or preference than larger smolts or adults (Vancil et al 1979, Spigarelli and Thommes 1979). However, brown trout ≥250mm in the Chattahoochee River survived temperatures as high as 27.5°C while smaller brown trout were absent, suggesting larger fish are more heat tolerant than smaller fish (Biagi and Martin 1992).

Unlike conditions in many test protocols reviewed in the literature neither temperature nor flow in the Chattahoochee River remains static. Incipient upper lethal temperature and lethal temperature tests have historically been conducted with larval fish or smolts. The fish are tested in static flow aquaria where they do not have to maintain their equilibrium while swimming against a current. The fish are plunged into the test temperature after initial acclimation to some lower temperature. This sudden thermal shock would not be experienced by trout in the Chattahoochee River.

The typical test endpoint is mortality or the lack of mortality. Salmonids exposed to high temperatures, for time intervals shorter than lethal doses can experience higher predation rates (Coutant 1973), which raises the question of how to develop protective criteria from a test that measures mortality as the endpoint. CTM tests expose the test fish to constantly increasing water temperatures until the fish lose equilibrium. Based on thermograph data from the Chattahoochee River, the temperature usually does not increase beyond the CTM, but peaks somewhere below that temperature and then cools to what is considered 'acceptable' temperature.

This study was designed to determine the temperature tolerance of fingerling and adult trout of the strains stocked in the Chattahoochee River. We developed an artificial system to simulate high temperature conditions similar to those found in the Chattahoochee River.

Methods and Materials

The test apparatus consisted of a 2,650-L insulated reservoir and three 1.5-m diameter round tanks (Figure 2). Water was pumped from the reservoir to the three test tanks and flowed by gravity back to the reservoir. Total water in the system was approximately 2,650-3,028 liters. Chattahoochee River water was transported by truck approximately 100 km to the Walton Experiment Station where the

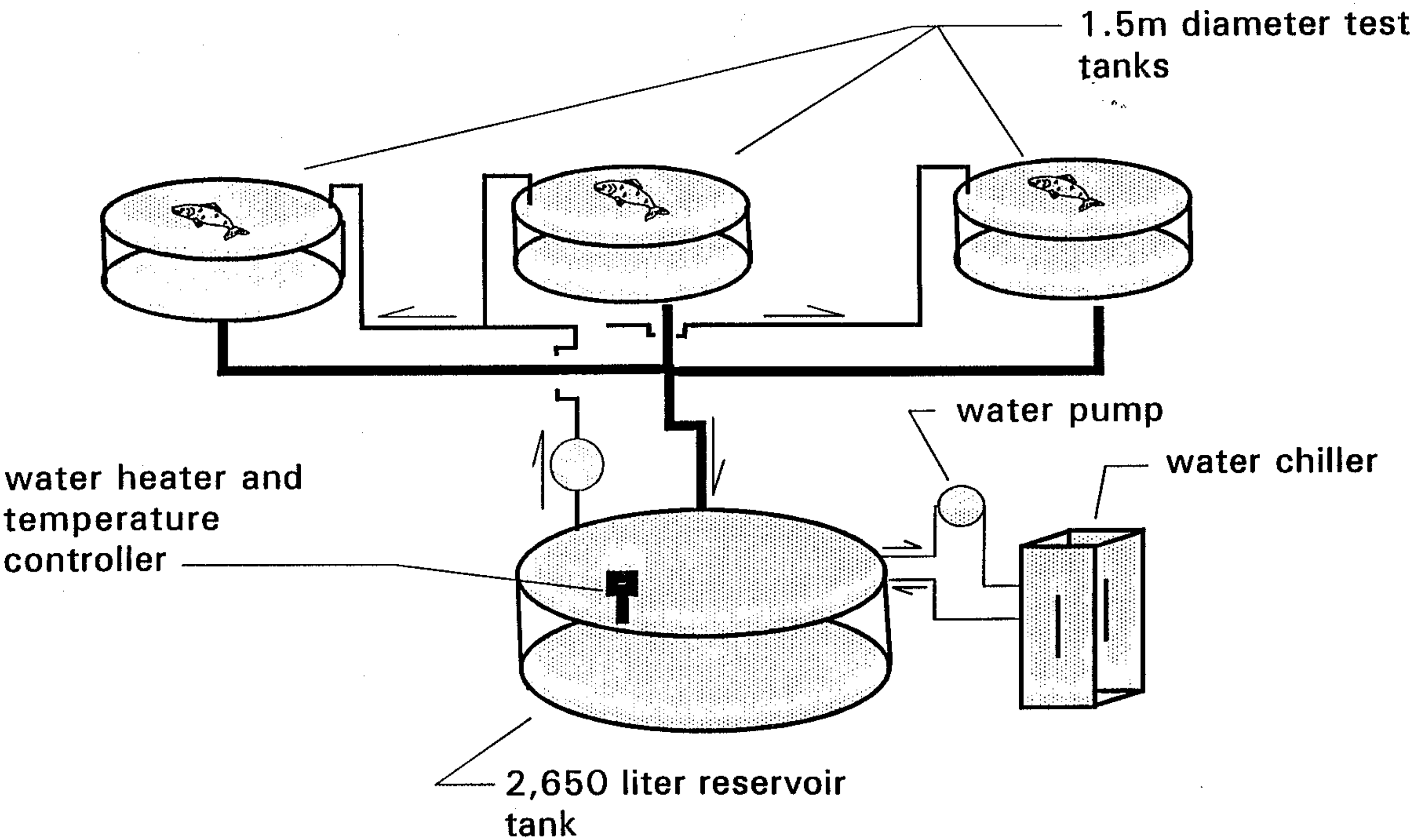

Figure 2. Schematic of test apparatus used to determine the tolerance of trout tested at 24, 26, 27, and 29°C.

experiments were conducted. Water pumped from the reservoir tank to the three test tanks was released so the water circulated in each tank. The water velocity in the test tanks was measured with a Pigmy Gurley flow meter and adjusted to 15 cm/s near the midpoint between the excluder rings and the outer edge of each tank. Excluder rings sixty-one centimeters in diameter were placed in the center of the test tanks to keep the trout in the current. Water exchange rates for the test tanks were approximately 26 L/min which produced a total water exchange every 17 minutes.

Water temperature was regulated using a Cleveland Process Corporation DRG-200 digital temperature controller which monitored water temperature and started a heater or chiller as necessary to maintain the set temperature. The heater was a 6,000 watt electric, stainless steel, emersion type heater. The chiller was a 1½ HP, 18,600 BTU chiller with a titanium heat exchanger coil. Room lights were on timers set to maintain a 14:10 hour light:dark photo period. Fluorescent lights were used along with ambient sunlight through translucent roof panels.

Walhalla strain brown (BNT) and Erwin strain rainbow trout (RBT) received from Buford Trout Hatchery, Wildlife Resources Division, Cumming, Georgia were used in the experiment. These fish were placed in the three test tanks at a minimum rate of five adult fish or 10 juvenile fish per tank. Some tests were run with fewer than the goal of five adults or 10 juvenile trout per tank because some trout jumped out of the test tanks during the acclimation period. Target length for all adult trout (age 1) was 254mm. Target length was 76mm for juvenile (age 0) brown trout and 127mm for juvenile RBT, the approximate size at stocking in the

Chattahoochee River. Juvenile trout were fed approximately 0.5 grams commercial pelleted trout feed per tank once daily; adult trout were not fed during the experiment to moderate the buildup of ammonia and nitrite in the test apparatus. Not feeding the adult trout should not have affected the results of the test (Dickson and Kramer 1971).

The fish were acclimated to 20°C for at least seven days before testing. After acclimation, the temperature was increased 0.6°C every 75 minutes (0.008°C/min) until the test temperature was reached. This rate was based on an average rate of increase in the Chattahoochee River during warmwater events. The test temperatures selected were 24°C, 26°C, 27°C and 29°C. Test temperatures were maintained for 10 days or until all trout had lost equilibrium. Equilibrium loss was defined as the point at which the trout remained upside down for one revolution in the tank or for five seconds, whichever occurred first. The time of equilibrium loss was recorded with video monitors. Red incandescent lights were used for video-recording the fish at night.

Chattahoochee River water was placed in the test apparatus and treated with Bacta-Pur™ bacteria to inoculate the biofilter media. The apparatus was equipped with both a biofilter and a zeolite filter. Water quality was measured daily to assure that parameters were within acceptable ranges. Parameters tested included pH, dissolved oxygen, total hardness, alkalinity, nitrites, and ammonia. A Yellow Springs Instrument model 57 and an Orion model 210A were used for measuring dissolved oxygen and pH during part of the study. A Hach model FF-A1 test kit was used to test all other parameters including some dissolved oxygen and pH measurements. Water temperature was monitored with a Ryan TempMentor at 20 minute intervals.

Data were tested for normality using the Shapiro-Wilk test (Conover 1980) and analyzed using the Mann-Whitney rank sum test (Bradley 1968). All statistical analysis was performed using Statistix® version 4.1 software. Statistical significance was determined at $\alpha=0.05$.

Results

Test waters typically had 8.6 mg/L dissolved oxygen, 14 mg/L calcium carbonate measured as total hardness, and 21 mg/L total alkalinity. Water temperatures were maintained to ±1°C. Ammonia (NH_3) levels ranged from 0 to 0.01 mg/L during tests. Nitrite (NO_2) ranged from 0 to 5.12 mg/L during the acclimation period and tests. High nitrite levels were of short duration and tests were not conducted unless nitrite concentrations were below 0.2 mg/L.

All 16 tests were completed as planned except for the adult RBT tested at 24°C. The pool of fish allocated for this test succumbed to disease problems and all died before the test was completed. The number of trout in each test group is listed in Table 1. There was no significant difference in time to equilibrium loss among tanks within tests for RBT at 26°C and 27°C and for BNT at 27°C, as demonstrated by overlapping 95% confidence intervals (Figures 3 and 4). No significant difference existed between BNT and RBT tested at 29°C except adult BNT groups ‘b’ and ‘c’ were different but neither were significantly different from group ‘a’ (Figure 5). The data from juvenile BNT at 24 or 26°C and adult BNT at

Table 1. Number of trout tested per test tank during four temperature tolerance experiments.

Test Group	24°C			26°C			27°C			29°C		
	A	B	C	A	B	C	A	B	C	A	B	C
juvenile BNT	10	12	11	14	11	14	11	12	11	11	12	12
juvenile RBT	10	10	10	4	11	9	11	13	9	10	12	14
adult BNT	5	4	5	5	5	5	5	5	5	5	5	5
adult RBT	**	**	**	5	5	5	5	5	5	5	2	5

** Test not conducted

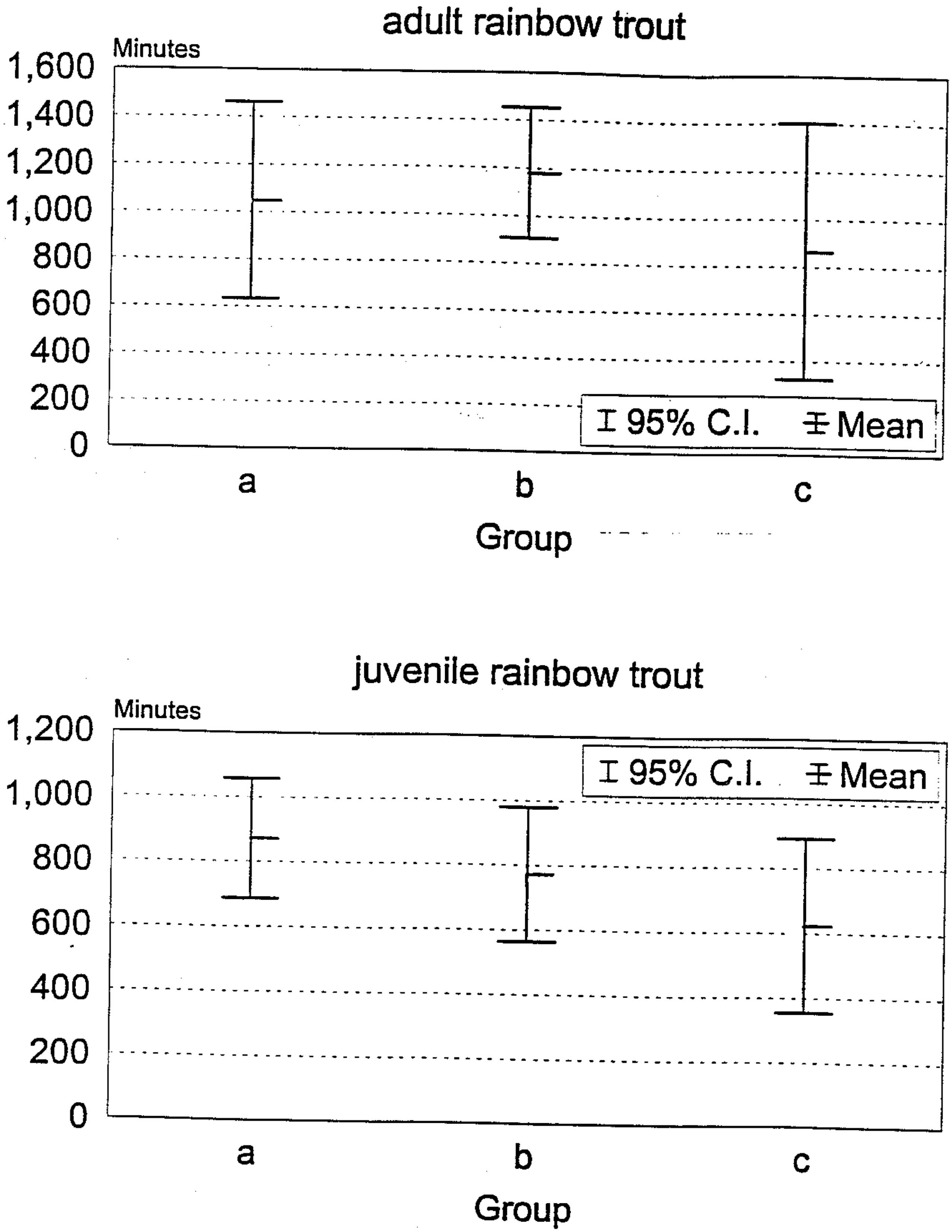

Figure 3. Mean time to equilibrium loss of juvenile and adult Erwin strain rainbow trout test groups with 95% confidence intervals. Trout were tested at 26°C.

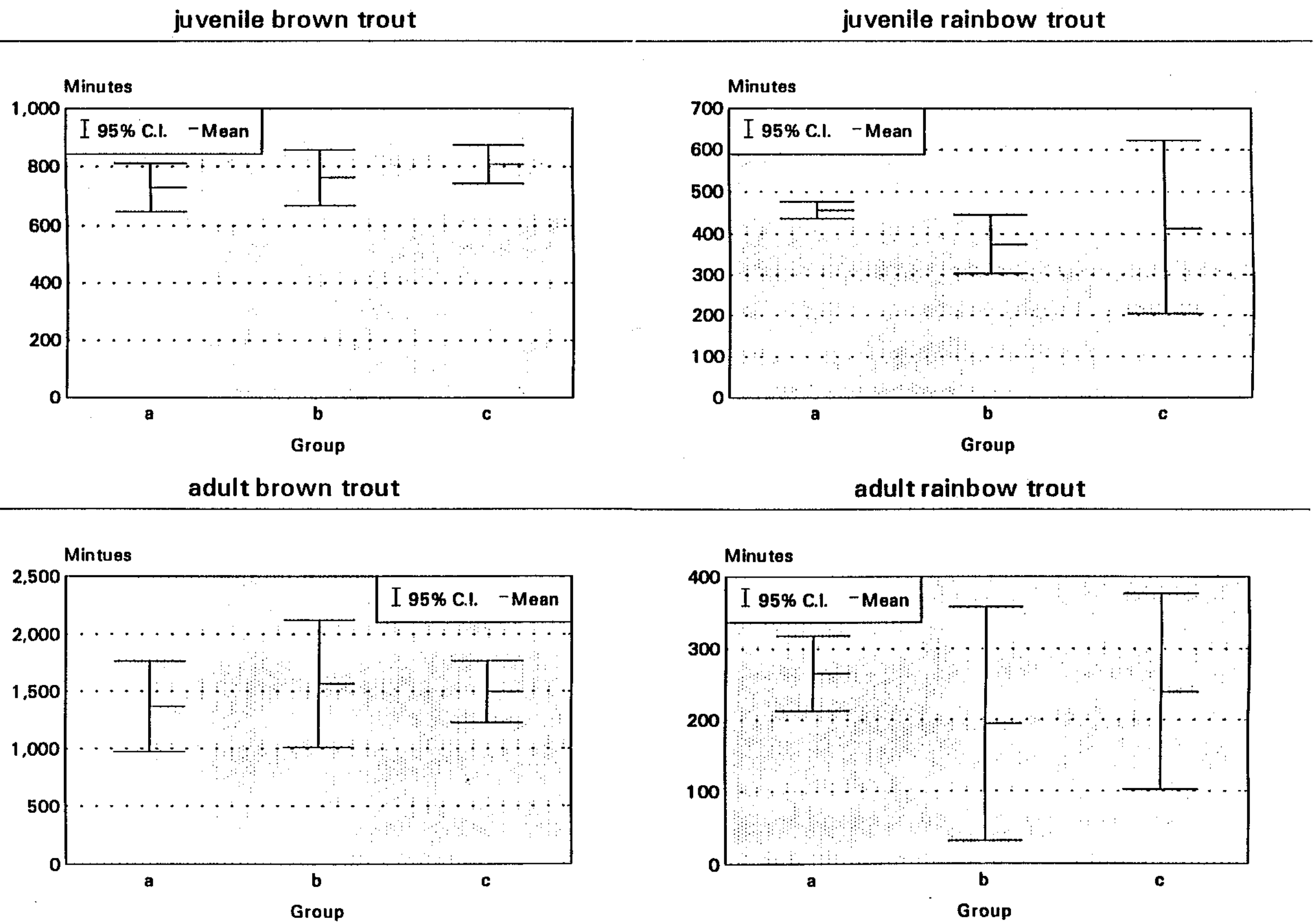

Figure 4. Mean time to equilibrium loss of juvenile and adult Erwin strain rainbow trout and Walhalla strain brown trout test groups with 95% confidence intervals. Trout were tested at 27°C.

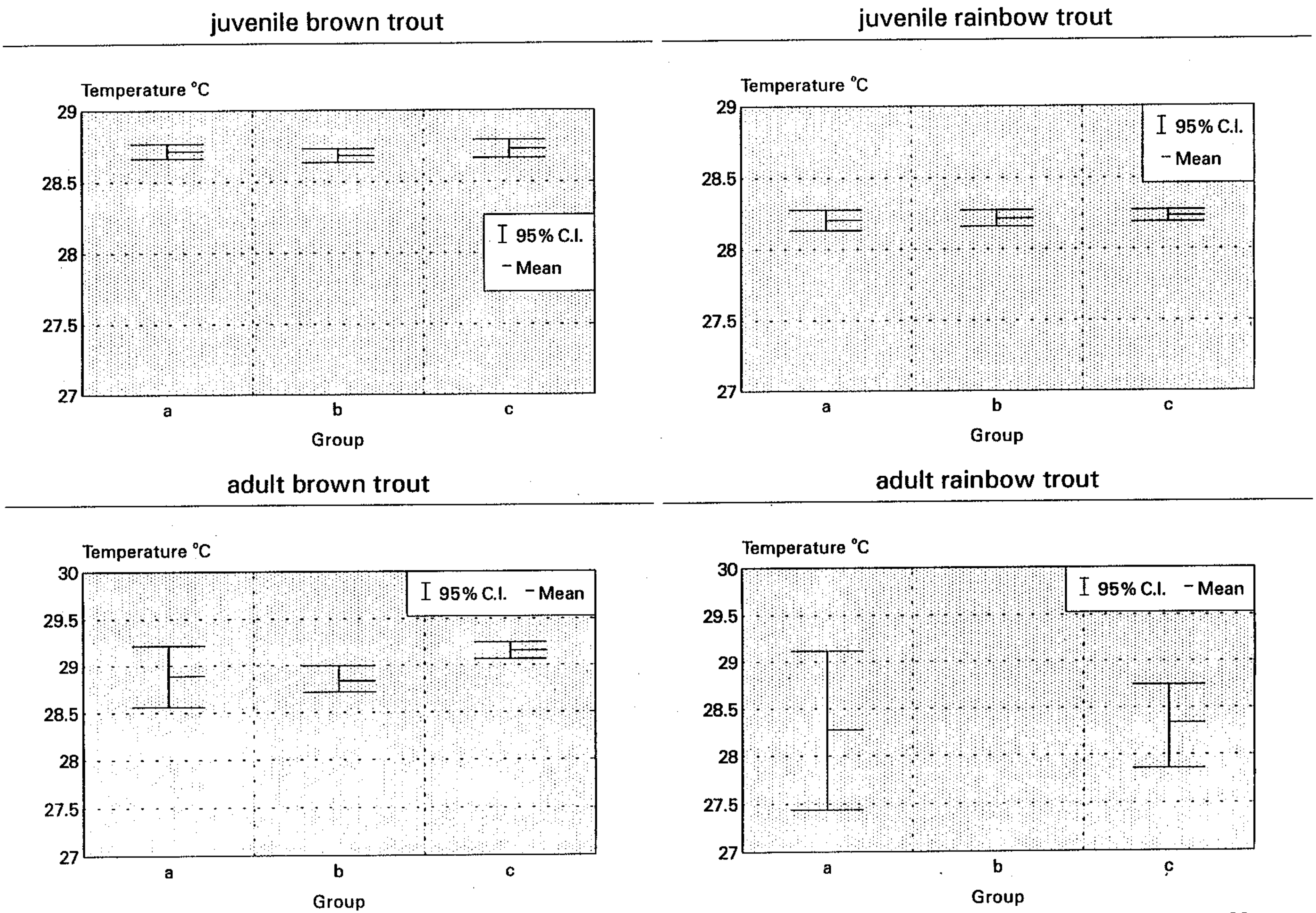

Figure 5. Mean temperature at equilibrium loss of juvenile and adult Erwin strain rainbow trout and Walhalla strain brown trout test groups with 95% confidence intervals. Trout were tested at 29°C. No data were presented for adult rainbow trout test group 'B' because the sample size was too small to generate the statistic.

26°C could not be statistically analyzed because only some fish lost equilibrium before the tests were stopped.

Data from test groups 'a', 'b' and 'c' were combined for each of the four trout test groups and for each temperature test for further analysis. Mean lengths of trout for each temperature test and actual mean test temperatures for each test are listed in Table 2.

All adult BNT and juvenile RBT tested at 24°C maintained equilibrium throughout the ten-day test period (Figures 6). Thirteen of 23 juvenile brown trout maintained equilibrium throughout the same test. Data from the juvenile BNT 24°C test group 'a' were lost because the video recorder malfunctioned. Four of the ten juvenile BNT in test group 'a' did not lose equilibrium during the test. Juvenile BNT displayed greater variability than juvenile RBT or adult BNT in their tolerance of 24°C.

BNT generally had higher tolerance than RBT in all tests above 26°C (Figure 7). Adult and juvenile BNT displayed greater variability in tolerance of 26°C than the adult and juvenile RBT. Six of 15 adult brown trout and one of 39 juvenile brown trout survived the ten-day test, while none of the RBT maintained equilibrium for the length of the ten-day test at 26°C (Table 3). None of the trout tested maintained equilibrium throughout the 27°C tests (Figure 8). Adult BNT tolerated 27°C longer and had the highest median tolerance of all trout tested. Juvenile BNT were the second most tolerant while juvenile RBT were third and adult RBT were least tolerant at 27°C. The time range over which trout lost equilibrium was much smaller at 27 and 29°C tests than found at the lower temperature tests.

Table 2. Mean total length of brown and rainbow trout tested for temperature tolerance. Mean test temperature determined by measurements at 20 minute intervals. No mean value is provided for the 29°C test because trout lost equilibrium as the temperature was increased to 29°C.

Test Group	Mean Length at Indicated Temperature (SE)				Mean Test Temperature (SE)		
	24°C	26°C	27°C	29°C	24°C	26°C	27°C
Juvenile BNT	88.4 mm (0.926)	91.8 mm (1.238)	102.7 mm (1.339)	99.9 mm (1.106)	23.7°C (0.031)	26.3°C (0.0344)	27.2°C (0.079)
Juvenile RBT	145.8 mm (5.266)	144.8 mm (6.412)	119.4 mm (2.987)	156.0 mm (3.418)	23.9°C (0.020)	25.3°C (0.162)	27.2°C (0.028)
Adult BNT	261.9 mm (3.198)	256.8 mm (3.756)	269.3 mm (5.277)	255.1 mm (4.476)	24.1°C (0.022)	25.4°C (0.013)	26.9°C (0.024)
Adult RBT		297.6 mm (2.458)	270.8 mm (5.649)	231.3 mm (5.444)		26.3°C (0.052)	27.0°C (0.057)

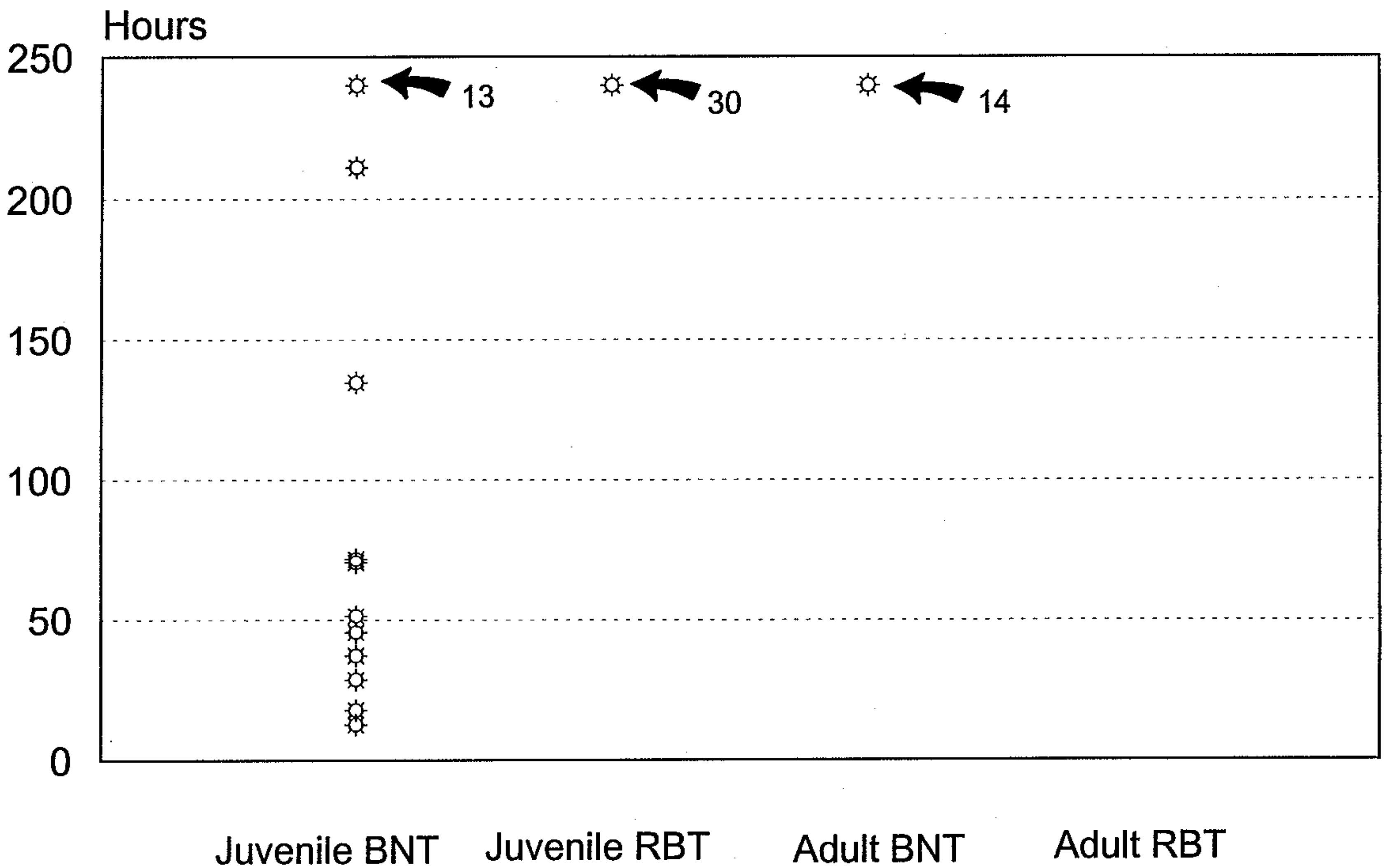

Figure 6. Time elapsed before equilibrium was lost for two sizes of Walhalla strain brown trout (BNT) and one size of Erwin strain rainbow trout (RBT) tested at 24°C. Tests were terminated after 240 hours (10d).

Note: juvenile BNT N=23, juvenile RBT N=30, adult BNT N=14.

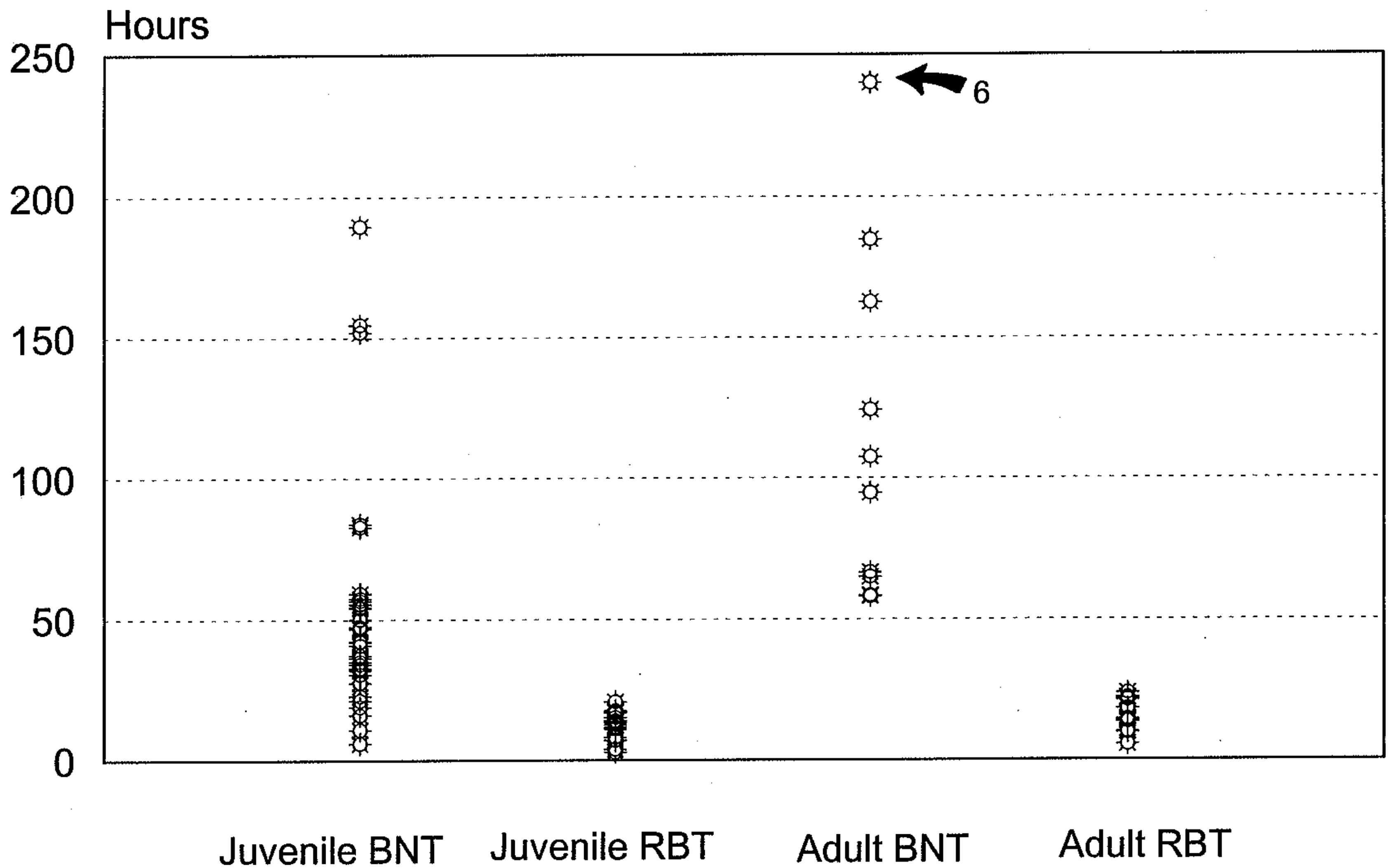

Figure 7. Time elapsed before equilibrium was lost for two sizes of Walhalla strain brown trout (BNT) and Erwin strain rainbow trout tested at 26°C. Tests were terminated after 240 hours (10d).

Note: juvenile BNT N=39, juvenile RBT N=23, adult BNT N=15, adult RBT N=15.

Table 3. Percentage of trout that lost equilibrium during four 10-day temperature tolerance experiments.

Test Group	24°C				26°C				27°C				29°C			
	A	B	C	Total	A	B	C	Total	A	B	C	Total	A	B	C	Total
Juvenile BNT	60	41	45	48	93	100	100	97	100	100	100	100	100	100	100	100
Juvenile RBT	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100
Adult BNT	0	0	0	0	60	60	60	60	100	100	100	100	100	100	100	100
Adult RBT	*	*	*	*	100	100	100	100	100	100	100	100	100	100	100	100

*Test not conducted

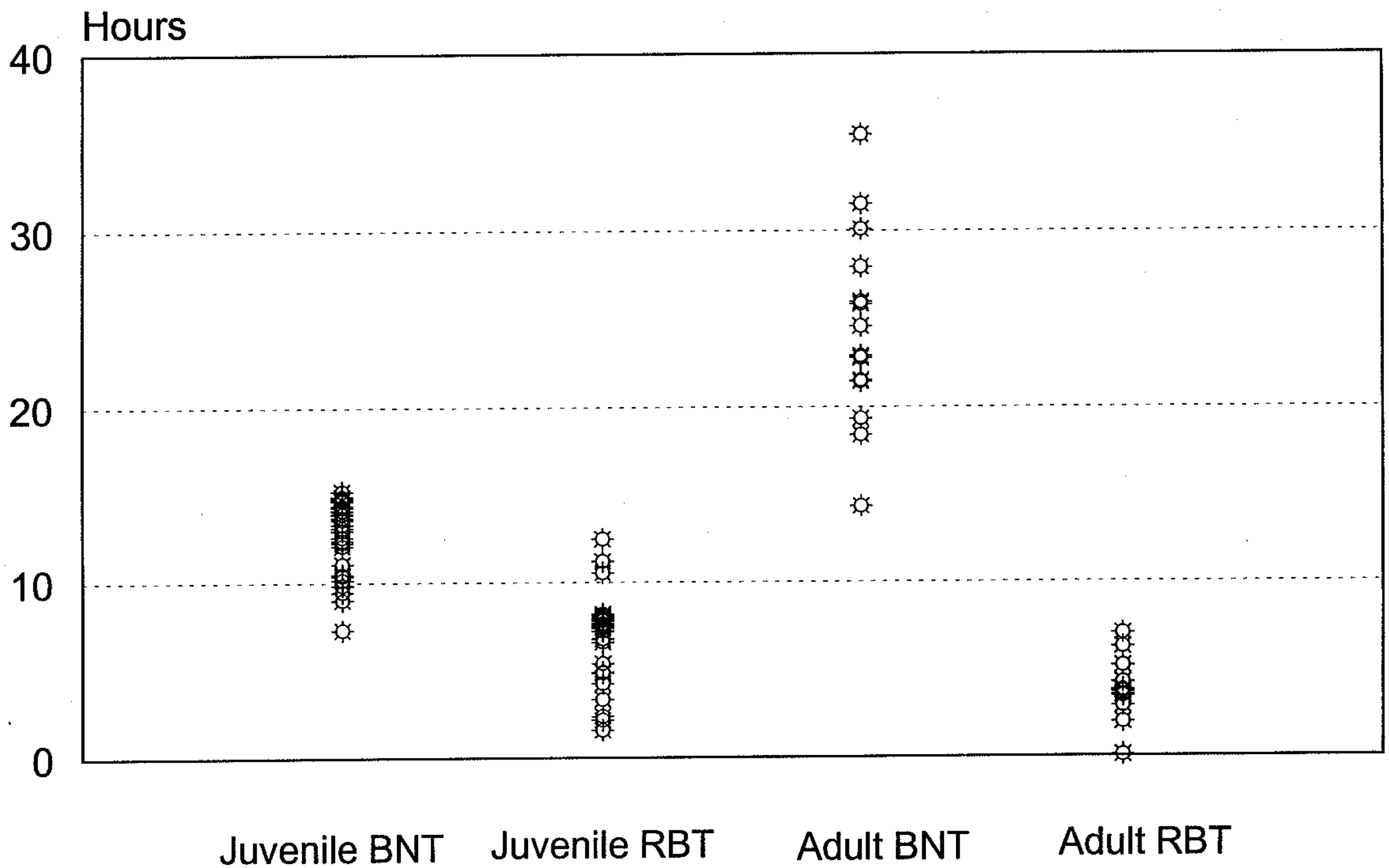

Figure 8. Time elapsed before equilibrium was lost for two sizes of Walhalla strain brown trout(BNT) and Erwin strain rainbow trout (RBT) tested at 27°C.

Note: juvenile BNT N=34, juvenile RBT N=32, adult BNT N=15, adult RBT N=15.

The 29°C exposure test results were presented differently because all but seven trout tested lost equilibrium before the test temperature was reached (Figure 9). All adult brown trout lost equilibrium above 29°C (four at 29.1 and three at 29.2°C). The tests and the results are similar to a CTM test. Therefore, the results are listed as the temperature at which equilibrium was lost. Again, the order of tolerance for the fish was adult BNT> juvenile BNT>adult RBT>juvenile RBT. Here the adult RBT were more tolerant than the juvenile RBT.

Adult BNT consistently had the highest median tolerance to the three upper test temperatures. Juvenile BNT were consistently the second most tolerant. Adult RBT were third most tolerant except at 27°C where juvenile RBT were third. Results of tests for normality and statistical significance are presented in Table 4. The distributions of time to equilibrium loss for juvenile and adult RBT at 26°C were not significantly different (Mann-Whitney rank sum test, P-value=0.5606). Distributions for juvenile and adult RBT tested at 27°C and 29°C were significantly different (P-value=0.0028 and 0.0290, respectively). Distributions for juvenile and adult BNT tested at 27°C and 29°C were also significantly different (P-value<0.0001 and P-value=0.0001).

Discussion and Conclusions

Juvenile trout tolerance of 24°C was comparable to Cherry et al. (1977) 7-day upper lethal temperature results. The 7-day upper lethal temperature is the highest temperature trout can tolerate for seven days with no mortality. Cherry et al. (1977) found that the 7-day upper lethal temperature for 50 - 100mm RBT was 25°C. The

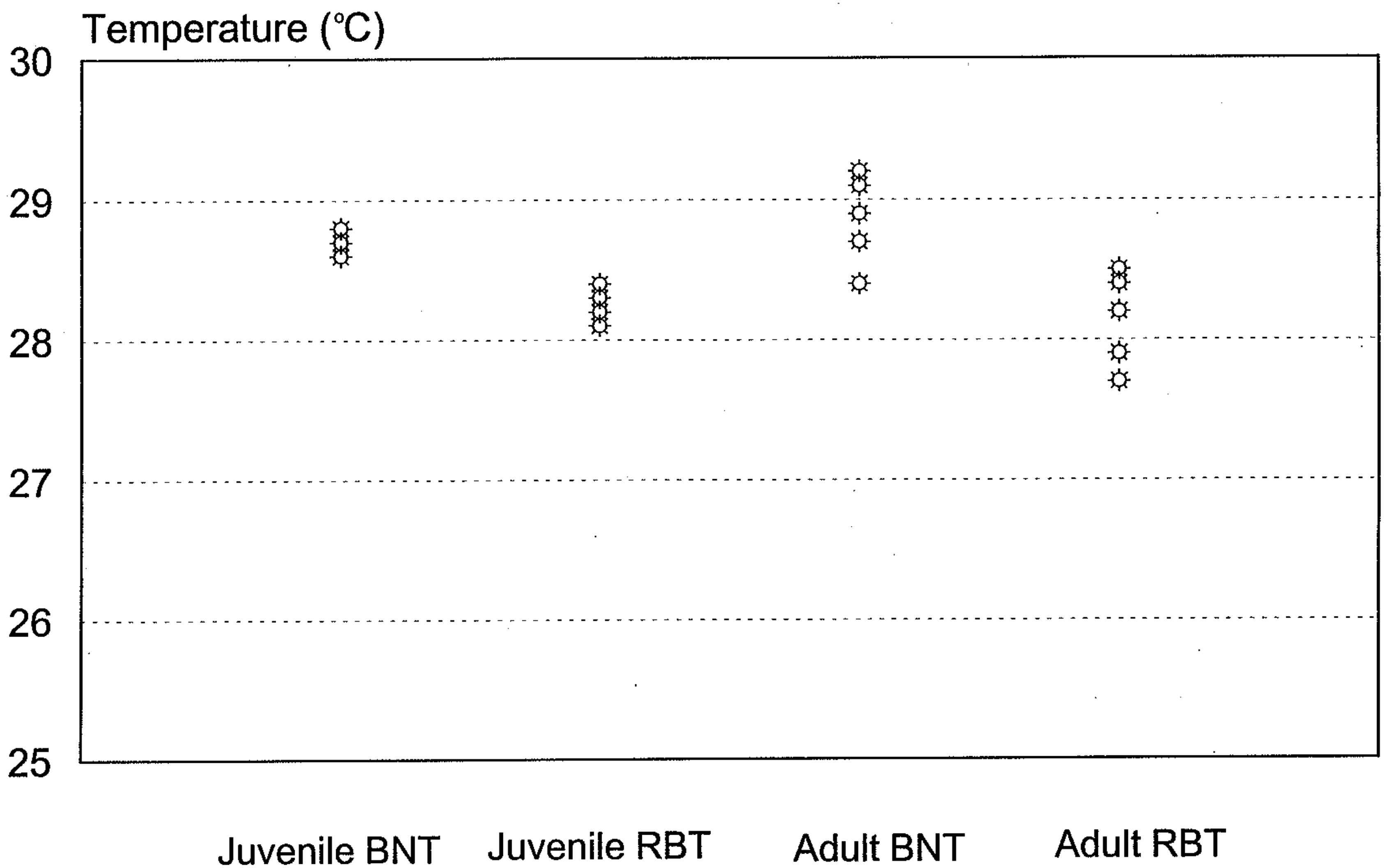

Figure 9. Temperature at equilibrium loss for two size groups of Walhalla strain brown trout (BNT) and Erwin strain rainbow trout (RBT). Study designed to expose trout to 29°C.

Note: juvenile BNT N=35, juvenile RBT N=36, adult BNT N=15, adult RBT N=10.

Table 4. Tolerance of trout tested at three temperatures. Tolerances measured as minutes of exposure to test temperature until equilibrium loss occurred except for 29°C tests where tolerance is listed as temperature at which equilibrium was lost. The Shapiro-Wilk test was used for testing normality. The Mann-Whitney Rank Sum test was used for comparisons between Test Groups (significance determined at $\alpha=0.05$). Matching letters signify no significant difference between Test Groups.

Test Group	Test Temperature	Normal Distribution	Statistical Significance	Minimum Tolerance	Median Tolerance	Maximum Tolerance
Juvenile BNT	26°C	N/A	N/A	357 min	2,538 min	14,400 min*
	27°C	no	A	436 min	799 min	913 min
	29°C	no	B	28.6°C	28.7°C	28.8°C
Juvenile RBT	26°C	yes	C	161 min	796 min	1,229 min
	27°C	no	D	92 min	453 min	747 min
	29°C	no	E	28.1°C	28.2°C	28.4°C
Adult BNT	26°C	N/A	N/A	3,476 min	14,400 min*	14,400 min*
	27°C	yes	F	858 min	1,474 min	2,127 min
	29°C	yes	G	28.4°C	28.9°C	29.2°C
Adult RBT	26°C	yes	C	323 min	1,258 min	1,410 min
	27°C	yes	H	4 min	222 min	420 min
	29°C	no	I	27.7°C	28.4°C	28.5°C

Statistical tests were not applicable (N/A) in some tests because the tests were terminated before all fish had lost equilibrium. In these cases, the tolerance listed and marked with an '*' denotes a fish or a group of fish that did not loose equilibrium before the ten-day test was terminated.

7-day upper lethal temperature of BNT of the same size was 23°C. We found that all juvenile RBT tested at 24°C survived ten days suggesting the 7-day upper lethal temperature is higher than 24°C. Of the juvenile BNT tested at 24°C, 48% lost equilibrium before test termination suggesting the upper lethal temperature is lower than 24°C for this size of BNT.

Our test results for 26, 27 and 29°C tests showed that the trout had lower tolerances than those tested in no flow conditions. Vancil et al. (1977) found that McConaughy strain RBT (mean TL 53.8 mm) acclimated to 20°C and tested in non-flowing water at 26°C had a median tolerance of 6,929 min (SD 5,457.7). A domestic strain RBT (from a Plymouth Rock, Massachusetts hatchery) had a median tolerance of 2,160 min (SD 2,096.1) under the same test conditions, 1/3 the tolerance of the McConaughy strain. Our juvenile RBT under flowing water conditions had nearly 1/3 the median tolerance of Vancil's domestic strain at the same test temperature. Interestingly, the McConaughy and domestic strains cited above exhibited the same high variability that was found in our study. The lower tolerance exhibited by Erwin strain RBT may be attributed to flow, strain, water quality, or a combination of those factors.

Tolerance varied with size and species. Although studies have found that fry or larval fish have a higher temperature tolerance than fingerlings or smolts (Vancil et al. 1977, Bishai 1960), it appears that adult trout are also more tolerant than fingerlings or smolts. Adult BNT in our study had a median tolerance of 14,400 min at 26°C which was much greater than the fingerling McConaughy strain RBT tested by Vancil et al. (1977). Adult BNT had the highest overall tolerance of both species and sizes we tested, while juvenile BNT had the lowest tolerance at 24°C. The juvenile BNT we tested at 26°C had a median tolerance of 2,538 min. This is more tolerant than adult Erwin RBT, and more tolerant than the domestic strain RBT tested by Vancil et al. (1977), but less tolerant than the McConaughy strain RBT. Juvenile RBT tolerated 27°C longer than adult RBT, however, demonstrating the danger of making broad statements about tolerances of all sizes of fish based on tests of one size.

Several researchers have tested BNT and RBT to find their CTM (Lee and Rinne 1980, Currie 1995, Vancil et al. 1977). One problem with comparisons among the studies is that different size trout were tested at different rates of temperature increase. Lee and Rinne (1980) tested 150-200mm BNT and RBT by increasing the temperature 0.02°C/min. Currie (1995) tested 40mm RBT and increased temperature 0.3°C/min. Vancil et al. (1977) used a rapid increase rate of 2.6°C/min while testing two size groups of RBT (mean lengths 86.7mm and 216.6mm). Our study's rate was slowest at 0.008°C/min.

Our study showed lower median CTM values than those reported in the literature. Lee and Rinne (1980) found BNT tested under their protocol to have a CTM value of 29.85°C. Reported CTM values for RBT have ranged from 29.35 to 30.6°C (Lee and Rinne 1980, Currie 1995, Vancil et al 1977). Juvenile BNT and RBT we tested had CTM values of 28.7 and 28.2°C, respectively. Adult BNT and RBT had CTM values of 28.9 and 28.4°C, respectively. This study was not designed to meet the CTM criteria, and the slow heating rate may have resulted in lower values. Flowing test conditions could also contribute to the lower values, but both factors should make the information more applicable to the Chattahoochee River conditions.

The high thermal tolerance of the Walhalla strain brown trout makes it well suited for stocking in the Morgan Falls Dam tailwater. Although the Erwin strain rainbow trout has demonstrated good long-term return-to-creel in the Chattahoochee River above Morgan Falls (Martin 1985), it has a lower temperature tolerance than McConaughy strain rainbow trout. It may not be the most appropriate rainbow trout strain to stock in the Morgan Falls Dam tailwater based on existing summertime water temperature patterns.

Recommendations

1. Continue stocking Walhalla strain brown trout in the Morgan Falls Dam tailwater.
2. Determine the feasibility of getting 50,000 McConaughy strain rainbow trout fingerlings for stocking in the Morgan Falls Dam tailwater. Replace Erwin strain rainbow trout with McConaughy strain if a reliable source is available.
3. Develop protective temperature criteria for the Chattahoochee River, Buford and Morgan Falls Dam tailwaters and recommend adoption by the Environmental Protection Division.

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