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RETURNS OF THREE YEAR-CLASSES OF SEA RANCHED ATLANTIC SALMON OF VARIOUS RIVER STRAINS AND THEIR HYBRIDS

by

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ABSTRACT

Three different river strains of 1974 year-class Atlantic salmon, released as small ($\bar{X}$ = 14.1 cm) 1-yr smolts in 1976 produced about 2.5 times more 2-sea-winter adult returns than grilse. The same three strains plus all six possible hybrid combinations planted in 1977 as large (>20 cm) 2-yr smolts returned approximately eight times more grilse than larger salmon. Four river strains and all 12 hybrid combinations of 1975 year-class salmon released as large (>18 cm) 1-yr smolts in 1977 returned about 1.4 times more grilse than larger salmon. The same four river strains and 12 hybrid combinations were produced in the 1976 year-class and released as 1-yr smolts in 1978. The 1976 year-class returned a much higher proportion as grilse than the 1975 year-class. One river strain, Big Salmon River, has accounted for approximately 47% of the identifiable grilse returns. Of the 505 marked grilse which have returned to date, 405 or 80% have been derived from crosses in which at least one parent was of Big Salmon River origin. Smolt age, size, quality and genetic origin appear to influence the size of returning grilse and grilse-larger salmon ratio.

INTRODUCTION

In 1974, experiments designed to examine the general combining ability of various Atlantic salmon stocks were initiated at the North American Salmon Research Center, New Brunswick, Canada. In 1975, 1976 and 1977, wild Atlantic salmon adults were collected from a number of different rivers and crossed with each other in all possible combinations. All the progeny from the different inter- and intra-strain crosses were marked and released as smolts into the Bay of Fundy near St. Andrews, New Brunswick. Smolt releases were made in 1976, 1977 and 1978. An earlier paper (Bailey and Saunders 1979) outlined some preliminary results of the first two smolt releases, which for the sake of completeness, are repeated in this report. In addition, the return information for the 3-sea-winter salmon returns of the 1976 release, the 2-sea-winter salmon returns of the 1977 release and the grilse returns of the 1978 release, all of which returned in 1979, are also included, giving a more complete analysis.

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MATERIALS AND METHODS

In 1974, broodstock were collected from three rivers and gametes were combined in a series of ten complete 3 x 3 diallel crossing sets. The three river strains were the Saint John (S), Big Salmon (B) and Dennis Stream (D). In both 1975 and 1976, broodstock were collected from four rivers and gametes were combined, respectively, in 11 and 12 complete 4 x 4 diallel crosses. The four river strains used in 1975 and 1976 were the Saint John, Big Salmon, Magaguadavic (M), and Rocky Brook (R). Details of the crossing design and rearing procedures have been given previously (Friars et al. 1979; Bailey and Saunders 1979). Briefly summarized, a complete diallel cross combines samples of male and female gametes from different river strains in all possible combinations. A diallel cross involving n river strains will yield n^2 distinct crosses of which n are pure strains (parents from the same river) and n (n-1) are hybrid strains (parents from different rivers). The 1974 year-class was composed of nine unique strains or strain crosses (genotypes) and the 1975 and 1976 year-classes included 16 genotypes.

Throughout this paper, the various genotypes are identified by a combination of two upper-case letters. The letters correspond to the first letters of the river names where broodstock were collected. The first letter identifies the river strain of the male parent and the second letter refers to the river strain of the female parent.

The first release of 22,068, 1^+ smolts was made in May, 1976. Prior to release, the entire 1974 year-class was graded and all fish which passed a 15-mm grader were retained in the hatchery. The fish released included large samples of the three pure strain genotypes which had been reared in heated water and a fourth group composed of a mixture of hybrid genotypes graded from the remaining tanks which had been maintained at ambient temperature. The four groups released in 1976 were marked by combinations of pelvic and adipose fin clips.

The second and third releases were made during late May of 1977 and 1978, respectively. The 1977 release included 31,969, 2^+-yr-smolts from the 1974 year-class and the entire 1975 year-class of 17,292 salmon which were 1^+-yr-old. The 1978 release included 26,592, 1^+-yr salmon of the 1976 year-class. All fish of the second and third releases were marked with coded, stainless steel micro-tags implanted in the cartilagenous snout tissue. Each genotype was batch marked with an unique code.

In the summers of 1977, 1978 and 1979, an adult collection trap was operated in the estuary of the release-capture stream. As each returning adult was captured, it was transferred to the broodstock holding facility, measured, and numerically tagged. All returns were held until the completion of maturation and spawning. In 1978, all fish were weighed immediately before they were spawned and the weights given are probably lower than when first captured. In 1979, each returning fish was weighed within 5 d of capture. Micro-tags were excised and decoded after the gametes were stripped. Scale samples were taken from all salmon which were not micro-tagged so that hatchery origin and ages could be determined.

RESULTS AND DISCUSSION

In 1977, 18 grilse from the 1974 year-class, 1^+ smolts were captured. In 1978, 316 adult salmon were captured, including 47 2-sea-winter salmon of the 1974 year-class, 1^+ smolts, 234 grilse from the 1974 year-class, 2^+smolts and 34 grilse of the 1975 year-class, 1^+ smolts. In 1979, 351 adult salmon were captured, including 10 3-sea-winter salmon from the 1974 year-class, 1^+ smolts, 30 2-sea-winter salmon from the 1974 year-class, 2^+ smolts, 25 2-sea-winter salmon from the 1975 year-class, 1^+ smolts, and 286 grilse from the 1976 year-class, 1^+ smolts. These results are summarized by genotype according to year-class and smolt age in Tables 1-4.

Recent studies have shown that many individuals in hatchery populations will not reach the minimum size necessary to undergo the physiological changes of smoltification in 1^+-yr (Thorpe and Morgan 1978, Bailey et al. 1980). As a result, these small individuals probably do not develop salinity tolerance and are incapable of survival at sea. Because the 1975 and 1976 year-classes were not graded prior to release, the effective number of smolts was lower than indicated above. Since it is possible to estimate the proportion of smolts from sample length-frequency distributions taken in the November prior to smolting, all return percentages are based on estimates of the effective number of smolts rather than the total number of fish released.

The ratio of grilse to larger salmon returns has been variable between both year-classes and smolt ages. The first release of relatively small 1^+ smolts of the 1974 year-class returned three times more 2- and 3-sea-winter salmon than grilse (Table 1). Very large 2^+ smolts of the same year-class returned almost eight times more grilse than larger salmon (Table 2). The 1975 year-class of relatively large 1^+ smolts returned approximately 1.4 times more grilse than larger salmon (Table 3). These results clearly support Ritter's (1972, 1975) observations that smaller, younger smolts are more likely to return as larger salmon than grilse. The smallest 1^+ smolts returned the lowest percent of grilse, the large 2^+ smolts returned the largest proportion of grilse and the percentage grilse return of the relatively large 1^+ smolts was intermediate. These results suggest the important influence of smolt age and size on the age at first maturity.

However, the anticipated ratio of grilse to larger salmon returns of the moderately large 1976 year-class, 1^+ smolts does not appear to conform to this pattern. The percent grilse return alone was more than two times higher than the total return of any previous year-class (Table 4). At the time of reporting (August 1980), less than 20 2-sea-winter salmon had returned. A generous projection of 50 larger salmon returns will produce a grilse:salmon ratio of 5.7:1. Since the 1976 year-class, 1^+ smolts were smaller than those of the 1975 year-class, additional factors such as smolt quality or environmental conditons may also exert an important influence on the age at first maturity.

Although the data are too few to make detailed comparisons among all genotypes, marked strain differences in the percent returns of grilse and larger salmon are apparent (Tables 5-9). Big Salmon River pure strain and strain crosses involving Big Salmon River broodstock consistently yielded the highest grilse and lowest larger salmon return percentages (Tables 5,7,9). Conversely, Saint John River pure strain and strain crosses produced the lowest grilse and highest larger salmon return percentages (Tables 6,8). Therefore, the age at maturity is not only influenced by smolt size and age, but also by genetic factors.

For all year-classes combined, approximately 4.5 grilse have returned for each larger salmon, giving a combined total biomass of approximately 1,640 kg with grilse accounting for 1,220 kg or 74% of the total. An important objective of a sea ranching operation is to maximize the production of fish flesh per smolt released. This is a function of return percentage and mean weight at return. Thus, the grilse:larger salmon return ratio is an important consideration in both the choice of a suitable stock and subsequent genetic selection goals. On the basis of our data, the critical ratio of grilse:larger salmon is approximately 2.3:1. Of the river stocks evaluated, to date, Big Salmon River fish consistently yielded the highest return percentages. Since the grilse:larger salmon ratio is approximately 35:1, selection for grilse is strongly implicated for this strain.

The results of this study indicate that smolt age, size, quality and genetic origin all influence the size and age at maturity of sea-ranched Atlantic salmon. Additional returns from the releases reported here and from subsequent plantings will provide further insight into the relative influence of these factors.

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Table 1. Atlantic salmon release and recapture summary for the 1974 year-class, 1^+ smolts released in 1976.

	Release 1976		Returns 1977		
Genotype	Number released	Mean F.L. (cm)	Number of returns	% return	Mean F.L. (cm)
DD	2942	13.6	5	0.17	51.4
SS	7950	14.5	7	0.09	56.4
BB	5464	14.3	2	0.04	55.5
Mixed	5712		2	0.04	60.0
Unknown[a]			2		
Total	22068	14.1	18	0.08	55.0

Returns 1978

Genotype	Number of returns	% return	Mean F.L. (cm)	Mean wt (kg)
DD	4	0.14	72.3	4.2
SS	30	0.38	78.3	4.6
BB	5	0.09	60.2	2.0
Mixed	7	0.12	75.7	3.8
Unknown[a]	1		60.0	2.5
Total	47	0.22	75.0	3.6

Returns 1979

Genotype	Number of returns	% return	Mean F.L. (cm)	Mean wt (kg)	Total % return
DD	2	0.07	73.0	4.4	0.37
SS	1	0.01	79.0	7.0	0.48
BB	2	0.4	75.5	5.3	0.16
Mixed	1	0.02	80.0	6.1	0.18
Unknown[a]	4		79.6	6.5	
Total	10	0.05	77.5	5.8	0.34

[a]Includes salmon in which the identifying fin clips are not recogninzable. Scale ages correspond with those of identifiable fish.

Table 2. Atlantic salmon release and recapture summary for the 1974 year-class, 2^+ smolts released in 1977.

	Release 1977		Returns 1978				Returns 1979				
Genotype	No. rel.	Mean F.L. (cm)	No. ret.	% ret.	Mean F.L. (cm)	Mean wt (kg)	No. ret.	% ret.	Mean F.L. (cm)	Mean wt (kg)	Total % ret.
DD	2546	20.0	3	0.12	55.7	1.6	1	0.04	73.0	5.0	0.16
DS	3337	19.3	5	0.15	60.0	1.7	3	0.09	73.8	4.6	0.24
DB	3750	18.3	16	0.43	57.3	1.7	2	0.05	72.5	4.8	0.48
SD	2538	20.9	4	0.16	57.0	1.7	6	0.24	76.4	5.8	0.39
SS	4374	21.2	19	0.43	63.4	1.9	6	0.14	78.9	6.0	0.57
SB	5626	20.0	44	0.78	61.0	2.1	1	0.02	78.0	5.4	0.80
BD	740	20.2	10	1.35	59.7	2.2	0				1.35
BS	4076	19.4	12	0.29	60.5	2.0	1	0.02	78.7	5.7	0.32
BB	4982	21.1	94	1.89	61.2	2.2	2	0.04	73.7	4.8	1.93
Unknown[a]			27		60.4	2.0	8		73.9	4.4	
Total	31969	20.0	234	0.73	60.8	2.1	30	0.09	77.8	5.2	0.83

[a]Includes salmon which lost micro-tags. Scale ages correspond with those of identifiable fish.

Table 3. Atlantic salmon release and recapture summary for the 1975 year-class, 1^+ smolts released in 1977.

	Release 1977		Returns 1978				Returns 1979				
Genotype	No. rel.[a]	Mean F.L. (cm)[b]	No. ret.[b]	% ret.	Mean F.L. (cm)	Mean wt (kg)	No. ret.	% ret.[a]	Mean F.L. (cm)	Mean wt (kg)	Total % return[a]
MM	879	19.5	2	0.23	57.5	1.6	1	0.11	74.0	4.8	0.34
MS	643	19.7	0				3	0.47	71.7	4.4	0.47
MR	974	19.5	0				0				0
MB	963	18.3	2	0.21	56.5	1.0	0				0.21
SM	422	19.3	0				1	0.24	78.0	5.4	0.24
SS	969	17.3	1	0.10	53.0	1.2	4	0.41	74.1	4.8	0.51
SR	1063	18.6	0				2	0.19	78.5	5.9	0.19
SB	952	17.0	2	0.21	51.0	1.4	0				0.21
RM	313	19.7	0				0				0
RS	905	18.4	1	0.11	55.0	1.4	2	0.22	72.5	4.1	0.33
RR	791	18.7	1	0.13	57.0	1.6	1	0.13	71.0	3.6	0.26
RB	815	17.4	3	0.37	56.0	1.7	0				0.37
BM	360	18.3	0				0				0
BS	327	17.7	0				1	0.31	67.5	3.6	0.31
BR	715	17.7	3	0.42	61.7	2.0	0				0.42
BB	1451	16.5	14	0.96	58.6	2.0	1	0.07	72.0	5.0	1.03
Unknown[c]			5		60.0	2.1	9		66.8	3.5	
Total	12534	18.2	34	0.27	57.9	1.8	25	0.20	70.7	4.3	0.47

[a]Corrected for effective smolt release based on bimodal length-frequency distributions of samples taken in November, 1976.

[b]Mean smolt fork lengths are not corrected and underestimate effective smolt fork length by 1.5-2.5 cm.

[c]Includes salmon which lost micro-tags. Scale ages correspond with those of identifiable fish.

Table 4. Atlantic salmon release and recapture summary for the 1976 year-class, 1^+ smolts released in 1978.

	Release 1978		Returns 1979			
Genotype	No. released[a]	Mean F.L. (cm)[a]	No. of returns	% return	Mean F.L. (cm)	Mean wt (kg)
MM	455	20.8	3	0.66	57.7	2.0
MS	420	21.3	7	1.67	59.6	2.2
MR	565	20.6	11	1.95	55.2	1.8
MB	1477	18.0	12	0.81	57.8	2.3
SM	137	23.1	0			
SS	1058	19.4	8	0.76	55.5	2.0
SR	539	20.4	1	0.19	53.5	1.6
SB	939	18.6	6	0.64	57.8	2.2
RM	283	19.4	2	0.71	54.0	1.9
RS	306	22.0	2	0.65	54.0	1.9
RR	942	17.7	5	0.53	54.6	1.8
RB	1499	18.0	17	1.13	54.4	1.8
BM	397	20.8	10	2.52	58.6	2.5
BS	1037	18.5	8	0.77	59.5	2.0
BR	1171	18.4	21	1.79	57.2	2.2
BB	4618	15.5	129	2.79	58.5	2.3
Unknown[b]			44		58.6	2.3
Total	15843	18.0	286	1.81	57.8	2.2

[a]Corrected for effective smolt release based on bimodal length frequency distributions of samples taken in November, 1977.

[b]Includes salmon which lost micro-tags. Scale ages correspond with those of identifiable fish.

Table 5. Percent grilse returns of 1974 year-class, 2^+ smolts released in May, 1977 and recaptured during the summer of 1978.

		Dams			
		Dennis Stream	St. John	Big Salmon	Sire means
Sires	Dennis Stream	0.12	0.15	0.43	0.23
	St. John	0.16	0.43	0.78	0.46
	Big Salmon	1.35	0.29	1.89	1.18
	Dam means	0.54	0.29	1.03	

Table 6. Percent 2-sea-winter salmon returns of 1974 year-class 2^+ smolts released in May, 1977 and recaptured during the summer of 1979.

		Dams			
		Dennis Stream	St. John	Big Salmon	Sire means
Sires	Dennis Stream	0.04	0.09	0.05	0.06
	St. John	0.24	0.14	0.02	0.13
	Big Salmon	0	0.02	0.04	0.02
	Dam means	0.09	0.08	0.04	

Table 7. Percent grilse returns of 1975 year-class, 1^+ smolts released in May, 1977 and recaptured during the summer of 1978.

		Dams				
		Magaguadavic	St. John	Rocky Brook	Big Salmon	Sire means
Sires	Magaguadavic	0.23	0	0	0.21	0.11
	St. John	0	0.10	0	0.21	0.08
	Rocky Brook	0	0.11	0.13	0.37	0.15
	Big Salmon	0	0	0.42	0.96	0.35
	Dam means	0.06	0.05	0.14	0.44	

Table 8. Percent 2-sea-winter salmon returns of 1975 year-class, 1^+ smolts released in May, 1977 and recaptured during the summer of 1979.

		Dams				
		Magaguadavic	St. John	Rocky Brook	Big Salmon	Sire means
S	Magaguadavic	0.11	0.47	0	0	0.15
i	St. John	0.24	0.41	0.19	0	0.21
r	Rocky Brook	0	0.22	0.13	0	0.09
e	Big Salmon	0	0.31	0	0.07	0.10
s						
	Dam means	0.09	0.35	0.08	0.02	

Table 9. Percent grilse returns of 1976 year-class, 1^+ smolts released in May, 1978 and recaptured during 1979.

		Dams				
		Magaguadavic	St. John	Rocky Brook	Big Salmon	Sire means
S	Magaguadavic	0.66	1.67	1.95	0.81	1.27
i	St. John	0	0.76	0.19	0.64	0.40
r	Rocky Brook	0.71	0.65	0.53	1.13	0.76
e	Big Salmon	2.52	0.77	1.79	2.79	1.97
s						
	Dam means	0.97	0.96	1.12	1.34	

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

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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)		Weight (g)		Numbers of fish	
		mean	SD	mean	SD	experimental[a]	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.

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February 28, 1983

Dr. Robert Behnke
Department of Fish and Wildlife Biology
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Fort Collins, Colorado 80523

Dear Dr. Behnke;

Enclosed is a draft of my paper on the temperature tolerance of redband trout and a paper on redband trout culture. I had not forgot your previous request, I wanted to send you the published version of the heat tolerance paper. I would appreciate your comments on my references to your work if not correctly stated. Please don't cite this paper, I'll send you the published version when completed.

I talked with Spencer Turner a few weeks ago concerning redband trout. His situation for planting redband eggs and for culture in Missouri sounds ideal. I hope redbands provide a useful fish for their needs.

We have requested 125,000 eggs from Ennis, Montana to be reared in Norfork, Arkansas. We hope to receive fingerlings by the spring of 1984. They will be stocked into the tailrace below Canyon Lake on the Guadalupe River in Comal County. Our main concern is that the fish will over-summer. The remainder of my research broodstock (100) will be stocked in this same fishery next month.

If I obtain additional information on redband trout from our fisheries I'll drop you a line.

Sincerely,

Al Sonski

Al Sonski
Research Biologist

ks

encl.

Culture of Redband Trout at a Warm-Water Hatchery

by

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ABSTRACT

Fingerling redband trout (Salmo sp.) were reared in earthen ponds during a winter and indoor tanks the following summer at a hatchery in central Texas to produce broodstock. Mean daily surface temperatures ranged between 49 and 80°F in ponds and between 67 and 75°F in tanks. While in ponds, fish grew from a mean total length of 5.9 in and a mean weight of 0.08 lb to 12.3 in and 0.74 lb. After over-summering in indoor tanks mean fish length was 15.2 in and mean weight 1.55 lb. Mean daily growth rates during pond and tank culture were 0.04 in and 0.004 lb and 0.02 in and 0.004 lb, respectively. Mean condition factors were 3774.02×10^{-7} for fish reared in ponds and 3823.90×10^{-7} for fish reared in tanks. Survival averaged 65.1% in ponds and 90.4% in tanks. There were no disease problems in ponds; diseases were minimal in tanks.

INTRODUCTION

Texas trout fisheries are dependent upon winter stocking of rainbow trout (Salmo gairdneri) from northern sources. These trout are stocked primarily in cold tailraces. Over-summer survival to enhance quality fishing is very limited. Warm-adapted trout would extend fishing into spring and summer months and additional waters could be stocked. Redband trout (Salmo sp.) are native to a few rivers in northern California and desert basin regions of Oregon (Behnke 1970; Schreck and Behnke 1971; Legendre et al. 1972; Hoopaugh 1974; Wilmot 1974; Behnke 1979). Upper lethal limits for redband trout, 80.2 - 81.3°F, indicate this species would over-summer in traditional tailrace fisheries and could enhance trout fishing in Texas (Sonski 1982).

Trout culture in the southern United States has primarily been restricted to winter because of water temperature requirements for survival (Hill et al. 1972; Rutledge 1973a; Newton et al. 1977; Jensen 1979; Flynn 1980). Nevertheless, Rutledge (1973b) cultured rainbow trout less than 0.38 lb (mean weight) in an outdoor raceway during the summer at 65 - 75^{o}F. In the laboratory Calderon (1965) reared rainbow trout in water at temperatures up to 84^{o}F.

Redband trout are cultured by a few state agencies (Behnke 1979) and at one federal hatchery (W. Orr, National Fish Hatchery, Ennis, Montana, personal communication). Conceivably, redband trout for stocking in Texas could result from artificial spawning and production by a Texas state hatchery. Success of this program would be limited by over-summering of broodstock.

This study describes culture of redband trout for 1 yr at a central Texas hatchery.

MATERIALS AND METHODS

Redband trout were obtained from the Fish Cultural Development Center, Bozeman, Montana in August, 1981. Their eggs were spawned (May, 1980) from wild fish captured in Parsnip Reservior, southeastern Oregon (W. Hosford, Oregon Department of Fish and Wildlife, Hines, Oregon, personal communication). Live fish (average total length = 5.4 in, average weight = 0.03 lb) were air-freighted (8 h) in plastic bags (1.5 - 2.0 lb/2.50 gal at 47^{o}F) packed in styrofoam boxes (18 x 18 x 9 in) to Heart of the Hills Research Station, Ingram, Texas. They were maintained for the first 13 wk in circular 250- or 500-gal fiberglass tanks at 58 - 68^{o}F. During this period all fish were fed a sinking commercial trout pellet (38% crude protein, 5% fat) at 3 - 4% body weight per day.

In November, 1981 fish were graded into two size groups, 4.0 - 5.4 in and 5.5 - 7.5 in (total length), and stocked into separate earthen ponds (Table 1). Water was added periodically to ponds to maintain a constant level until draining. Ponds were drained the following spring and the fish transferred to indoor circular tanks (Table 1). Fish from Pond A were placed into a cement tank with conical-shaped bottom; this tank was situated in a building enclosed with screens. Fish from Pond B were put in a fiberglass tank with a flat bottom, in a plastic-covered greenhouse equipped with exhaust fans to circulate air. Fresh spring water (pH = 7.7, total dissolved solids = 360 ppm) was continuously flowed through each tank (Table 1). Sleeve tubes with bottom notches were placed around center stand-pipes to remove water and large waste material from tank bottoms. The inside tank walls were scrubbed clean approximately every 2 - 4 wk. During July - October filamentous algae became overabundant and was removed from the greenhouse tank weekly to prevent sleeve tube clogging.

Pond fish were sampled at approximate 2-wk intervals (Table 2,3) to monitor growth and alter feeding rates. Sampling methods included angling and electrofishing. On three sampling dates no fish were collected in Pond B (Table 3) and average weight was estimated from weight gain in Pond A fish during the same growth period. At pond draining, fish were dipped from the drain box and two samples of fish taken. Tanks were also sampled at approximate 2-wk intervals; however, to reduce stress during periods of high water temperature (May - November) intervals were changed to 3 - 4 wk. During sampling, tanks were partially drained and a sample (Table 2,3) was randomly captured with a dip net. Sample fish were anesthetized in a quinaldine solution, measured for total length (in) and weight (lb), and then placed into a tub containing a 3% salt dip for 1 min before returning them to the water.

Pond fish were fed a commercial production trout pellet (38% crude protein, 5% fat) according to a standard table (Sterling H. Nelson and Sons, Murray, Utah). Feed rates were calculated for the number of fish stocked until April, when the number of fish in Pond A was visually estimated to be 100. During periods of cold weather they were fed only to satiation if less than the prescribed rate. Fish in the fiberglass tank were fed similarly except they were fed maintenance diets (Table 3) during June - November. Fish in the cement tank were fed maintenance diets (Table 2) throughout the culture period. Their food was the commercial production trout pellet during May - July but was changed to a commercial broodstock trout pellet (45% crude protein, 8% fat) during August - October. During a 14-day period in July, tank feeding rates were increased from 0.75 to 1.4% to administer a prescribed level of medication in the diet. All fish were fed half the daily ration each morning and afternoon. Feeding was discontinued the afternoon before and on sampling dates.

Growth rates expressed as increase in weight and length per day were calculated for fish in each pond and tank from total gain in length and weight divided by the number of culture days (Haskell 1959; Haskell et al. 1960; Piper et al. 1982). Feed conversions were calculated as net gain in weight divided by weight of feed fed. Standard deviation (Snedecor and Cochran 1978) was calculated for mean fish length and weight at stocking and draining. Condition factors (K) were calculated from mean fish weight (W) and length (L) at each sampling as $K = W/L^3$ (Haskell 1959; Piper et al. 1982).

Surface water temperature (Table 2,3) was recorded in the morning only, November, 1981 - January, 1982, and thereafter in the morning and afternoon. Mean morning and afternoon temperatures were calculated as the average of measurements collected during a growth period.

Fish in tanks were treated weekly for 3 h with a mixture of 0.1 ppm malachite green and 50.0 ppm formalin (Leteux and Meyer 1972) as prophylaxis from external protozoan parasites and fungus.

RESULTS AND DISCUSSION

Growth and Condition

Growth rates between ponds were similar (Table 4). Growth rate in weight was similar between tanks but the rate of increase in length was less in the cement tank than in the fiberglass tank. Fish grown in the cement tank were large when stocked; the feeding rate and type of feed maintained broodstock without increasing length considerably. Partial weight gain resulted from gonadal maturation evidenced in dissection of several fish at draining. Mean weight of redband trout at 2 years of age (June 9 in Table 2,3) was less than Kincaid (1981) reported for same aged domesticated rainbow trout.

Haskell et al. (1956), Haskell (1959) and Spence (1973) indicate trout growth rate increases as temperature increases but do not give data for water temperatures greater than 65°F. Growth rates obtained from the present study were similar to those achieved (0.001 - 0.006 lb/day) by redband trout reared at a cold-water hatchery at 54°F during the same time period (W. Orr, personal communication). For redband trout, increases in growth with increased temperature may be limited up to 75°F. Above this temperature heat stress may occur; Sonski (1982) noted redband trout ceased feeding at 78°F.

Redband trout fingerlings (mean weight = 0.013 lb) grow faster at 66°F than at cooler temperatures (P. Dwyer, Fish Cultural Development Center, Bozeman, Montana, personal communication) and Sonski (1982) found redband trout (mean weight = 0.064 lb) gained more weight when held at 68°F than at 59 or 73°F. Although temperatures in this study fluctuated 2 - 5 °F daily, the upper levels experienced were apparently not harmful as long as temperature decreased to 69 - 71°F at night. This water temperature regime was apparently conducive to good growth.

Condition factors of fish were similar between ponds and tanks (Table 5). They were lower than those (4055×10^{-7}) given for rainbow trout by Piper et al. (1982) but higher than those (3082×10^{-7}) of redband trout broodstock grown on a cold-water hatchery (W. Orr, personal communication). Differences in redband trout condition between hatcheries may result from differences in feeding rates. Fish grown at the cold-water hatchery were fed 0.5 - 0.7% body weight per day, while redband trout reared in the present study were fed 0.75 - 4.00% (Table 2,3).

Mortality

Natural mortalities were not observed in either pond, however at draining mortality was greater than 30% (Table 4). Most mortality was probably due to bird predation. Rutledge (1973a) reported mortality of 27 - 72% for brown (*Salmo trutta*) and rainbow trout respectively, reared in the winter in ponds at this hatchery. He attributed part of the mortality to great blue heron (*Ardea herodias*) predation. Substantial harvest mortality (22.4%) occurred when Pond A was drained on May 25. The primary cause was fish became trapped in aquatic vegetation and were unable to swim to the drain box. Water temperature at draining was 75°F; this probably increased stress of trapped fish. There was no harvest mortality for Pond B fish drained the previous March when the water temperature was 65°F.

Over-summering redband trout in shallow earthen ponds in central Texas would probably be impossible. Pond temperatures often reach 85°F which exceeds lethal limits for redband trout. Maximum daily afternoon temperatures in tanks (approximately 75°F) were probably stressful to trout, however each night water temperatures cooled to 69 - 71°F, decreasing stress. Sonski (unpublished data) showed 54% mortality of a sample of 50 redband trout (mean weight = 0.055 lb) held at 73°F for 70 days and a 50% mortality of 10 similar redband trout held at 77°F for 26 days.

Feeding and Feed Conversion

Feed conversions were lower (Table 4) than Rutledge (1973b) obtained (0.91) in summer raceway rainbow trout production but higher than obtained (0.26) for rainbow trout cultured in winter in similar ponds at this hatchery (Rutledge 1973a). Flynn (1980) reported feed conversions of 0.11 - 0.42 in winter rainbow trout production in earthen ponds in Alabama. For sibling redband trout broodstock cultured at a cold-water hatchery in raceways, the conversion was 0.77 (W. Orr, personal communication).

Feed conversion for redband trout cultured in ponds probably could be improved if the number of fish was known when feed rates were calculated; this would prevent overfeeding and waste. Stocking larger fish at a higher density (Table 4) was important to feeding activity. Fish in Pond A fed very readily while those in Pond B were cautious and easily scared at feedings. Good feeding activity was conducive to less feed waste. In raceway culture of redband trout feed utilization can be increased if fish are fed by a demand feeder (W. Orr, personal communication).

Broodstock held in cold-water (48 - 54^{o}F) hatcheries are fed 0.7 to 1.0% body weight per day to maintain growth and good condition (Piper et al. 1982). Feed recommendations for trout broodstock cultured in warm-water hatcheries apparently are not available. For trout production, Rutledge (1973b) suggested a feed rate of 1.0% for fish greater than 0.25 lb reared in 65 - 75^{o}F water. In this study feed rates as low as 0.75% were effective for maintaining broodstock in good condition in water less than 75^{o}F.

Water Quality

The water at this hatchery originates from a large spring and historically has been of high quality with dissolved oxygen concentrations at saturation or above. In all culture units water quality was sufficient and crowding minimum to provide healthy rearing conditions as evidenced in good growth and high survival at warm water temperatures. Spence (1973) showed if the density remains constant as size of fish increases, water flow-through rate required to limit ammonia (NH_4-N) to 0.5 ppm decreases but required flow rates increase with temperature. His data indicates that at 60°F, 100 lb of 15-in fish require a flow rate of about 6.0 gal/min (gpm) to limit ammonia to 0.5 ppm. Data were not given for higher water temperatures. In the present study, maximum loads in tanks (Table 1) approached levels recommended by Rutledge (1973b) of 1.0 gpm per 1.5 - 2.5 lb of fish cultured in water greater than 60°F.

As a general rule, Piper et al. (1982) indicates to avoid crowding trout should be held at densities in pounds per cubic foot no greater than 0.5 their length. As an example, the cement tank had a volume of 502 ft^3 and the average fish length was 15.5 in. This would allow 7.25 lb/ft^3 to be reared in the cement tank. Maximum density in this study was 0.17 lb/ft^3.

Diseases

Trout cultured in ponds had no disease problems; temperatures were low and water quality was good. In June, an outbreak of "ich" (*Ichthyophthirius* sp.) occurred in the cement tank. Three fish died before the parasite was brought under control with four daily treatments (4 h each) of 0.1 ppm malachite green and 50.0 ppm formalin. Later the same month about 20% of the fish in this tank developed small lesions on their sides. *Aeromonas hydrophila* was diagnosed as the causative agent; the bacteria was sensitive to terramycin (R. Jones, United States Fish and Wildlife Service, Pinetop, Arizona, personal communication). A few fish in the fiberglass tank also had similar symptoms. Fish in both tanks were fed a medicated feed diet (oxytetracycline, 0.09 oz/100 lbs fish/day) for 14 days. Effectiveness of the treatment was undetermined, however, increased feeding activity was noticed after treatment completion. The disease remained chronic until fall, when water temperatures decreased to

$68^{o}F$. Two fish died from the bacteria.

Approximately 20% of the trout in the cement tank developed symptoms of gas-bubble disease (bubbles in the eyes) in August. This is known to occur where there is a supersaturation of nitrogen or other dissolved gases (Weitkamp and Katz 1980). This saturation can be decreased by baffeling or agitating the water to increase circulation (P. Dwyer and C. Smith, Fish Cultural Development Center, Bozeman, Montana, personal communication). A portable surface aerator was run in the cement tank during the day and an air-lift pump was installed in the fiberglass tank. By the fall there were no symptoms of gas-bubble disease. One fish died, apparently due to this disease.

Sampling Concerns

Angling with artificial lures yielded large samples for the first four sampling periods (Table 2,3). Thereafter, fish would not accept lures and had, no doubt, become "conditioned". Boat-mounted electrofishing equipment was employed but was time consuming and did not collect an adequate sample; trout avoided the boat. Angling with live forage fish proved to be the most efficient sampling method although hooking mortalities occurred. Piper et al. (1982) suggested sampling ponds with a seine or lift nets. Although not attempted in this study, these methods may have proved useful.

Although 16 - 26% of the fish in indoor tanks were easily captured during routine collections, there apparently was considerable sampling variation. This was evident in three samples, in which fish had lower mean lengths and weights than previously (Table 2,3). Sampling variation was probably compounded by the fact that broodstock segregate by size (W. Orr, personal communication). Fish should have been more crowded before collection to assure a more representative sample.

RECOMMENDATIONS

Based on results of this study redband trout can be reared at a warm-water hatchery and grown from fingerling to broodstock size in a period of 1 year. Caution should be applied in situations where water temperatures and quality, and type of rearing facilities differ.

In good water quality at 65 - 75°F growth of redband trout fed 1 - 3% body weight per day will be sufficient to produce broodstock and a feeding rate of 1% will maintain them in good condition.

Weed control should be practiced to reduce harvest mortality in ponds and trout should be transferred to over-summering facilities before afternoon pond temperatures exceed 65°F. Over-summering in stagnant earthen ponds would probably result in mortality of redband trout if morning and afternoon water temperatures exceed 70 and 75°F, respectively.

In ponds wild-spawn juvenile redband trout should be stocked at densities of at least 200 fish/acre to encourage aggregate feeding activity. Mortality in ponds should be estimated to determine accurate feed rates.

Diseases should be diagnosed and may be treated with medicated feed, however, bacterial diseases may remain chronic as long as temperatures exceed 68°F.

Sampling broodstock greater than 1.0 lb should be conducted at least every 4 wk to adjust feed rates. Angling with natural baits may be used to sample ponds. Fish in tanks should be crowded before samples are taken to reduce sampling variation.

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I wish to express my appreciation to Ronald Major, United States Fish and Wildlife Service, Pinetop, Arizona for assistance in diagnosing diseases, to the staff of the Fish Cultural Development Center, United States Fish and

Wildlife Service, Bozeman, Montana, for their suggestions on trout culture; and to Wesley Orr, United States Fish and Wildlife Service, Ennis, Montana, and William Hosford, Oregon Department of Fish and Wildlife, Hines, Oregon, for providing data on redband trout.

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Table 1. Culture unit specifications and loading parameters for redband trout reared at Heart of the Hills Research Station, Ingram, Texas, November, 1981 - November, 1982.

Culture unit	Area (a)	Volume (ft^3)	Diameter (ft)	Flow rate (gal/min)	Maximum density (lb/ft^3)	Maximum loading (lb/gal/min)
Pond A	0.72	79,074	-	-	0.0013	-
Pond B	0.62	72,963	-	-	0.0003	-
Cement tank	-	502	20.7	50	0.17	1.73
Fiberglass tank	-	455	12.0	30	0.16	2.45

Table 2. Sampling dates, sample size, mean total length (in), mean weight (lb), mean surface water temperature (^{o}F) and feeding rate (% body weight/day) for redband trout cultured in an earthen pond and an indoor circular cement tank at Heart of the Hills Research Station, Ingram, Texas, November, 1981 - November, 1982.

Sampling date	Sample size	Fish length	Fish weight	Surface temperature AM	Surface temperature PM	Feed rate
			Pond A			
Nov 6	10	6.77	0.11			
				63.3	-	4.00
23	15	7.11	0.13			
				60.4	-	4.00
Dec 8	15	8.29	0.21			
				60.1	-	3.00
23	8	9.23	0.31			
				54.5	-	2.50
Jan 5	14	10.08	0.40			
				48.7	-	2.00
21	5	10.10	0.42			
				58.8	-	1.40
27	16	10.20	0.45			
				52.3	-	1.50
Feb 11	12	11.78	0.62			
				59.7	61.5	1.50
25	10	11.85	0.65			
				56.8	62.2	1.30
Mar 8	12	12.38	0.73			
				67.3	68.9	1.70
23	8	13.58	0.95			
				63.3	65.5	1.50
Apr 6	10	13.62	0.99			
				66.6	71.4	1.25
20	8	13.91	0.99			
				66.0	71.8	1.25
May 11	8	13.87	1.01			
				73.6	81.0	1.25
25	26	14.09	1.07			
			Cement Tank			
				68.9	71.8	0.75
Jun 9	10	13.94	0.87			
				68.5	71.6	0.75
Jul 14	11	14.63	1.09			
				68.9	72.1	1.00
Aug 9	12	13.81	0.93			
				69.1	71.4	1.00
Sept 8	12	14.44	1.16			
				68.0	70.3	1.00
Oct 7	11	14.39	1.25			
				66.9	69.3	1.00
25	48	15.48	1.63			

Table 3. Sampling dates, sample size, mean total length (in), mean weight (lb), mean surface water temperature (^{o}F) and feeding rate (% body weight/day) for redband trout cultured in an earthen pond and an indoor circular fiberglass tank at Heart of the Hills Research Station, Ingram, Texas, November, 1981-November, 1982.

Sampling date	Sample size	Fish length	Fish weight	Surface temperature		Feed rate
				AM	PM	
			Pond B			
Nov 6	10	5.00	0.05			
				62.8	-	4.00
24	6	6.03	0.08			
				61.2	-	4.00
Dec 8	0	-	0.11*			
				58.1	-	3.00
23	0	-	0.23*			
				53.2	-	2.50
Jan 5	9	8.13	0.21			
				50.4	-	2.25
21	9	8.45	0.22			
				54.1	51.6	1.50
Feb 11	0	-	0.33*			
				59.7	60.1	1.50
25	5	9.77	0.34			
				56.7	61.5	1.40
Mar 8	20	10.43	0.40			
			Fiberglass Tank			
				68.0	69.6	1.80
Mar 23	10	10.10	0.37			
				66.7	69.1	1.80
Apr 7	12	10.89	0.48			
				66.9	70.7	1.70
19	11	10.89	0.48			
				67.1	69.8	2.00
May 11	12	11.60	0.62			
				68.2	71.6	2.00
25	16	11.56	0.57			
				69.1	73.2	1.00
Jun 9	16	11.97	0.64			
				69.1	73.2	1.00
Jul 15	13	12.52	0.75			
				69.8	74.5	1.00
Aug 9	12	13.08	0.85			
				69.4	73.8	1.00
Sept 7	12	13.66	0.99			
				68.5	72.7	1.00
Oct 6	12	13.81	1.14			
				66.7	69.8	1.00
Nov 15	18	14.96	1.47			

* indicates weight was estimated from growth of similar fish cultured in another pond during the same period.

Table 4. Summary of information on culture of redband trout reared in earthen ponds and circular tanks at Heart of the Hills Research Station, Ingram, Texas, November, 1981-November, 1982.

Parameter	Pond A	Cement tank	Pond B	Fiberglass tank
Stocking				
date	Nov 6, 1981	May 25, 1982	Nov 6, 1981	Mar 8,1981
no. fish stocked	146	64	75	52
mean length-in (SD)*	6.77(0.03)	14.09(1.22)	5.00(0.59)	10.43(0.98)
mean weight-lb (SD)*	0.11(0.03)	1.07(0.34)	0.05(0.02)	0.40(0.14)
Draining				
date	May 25, 1981	Oct 25, 1982	Mar 8, 1982	Nov 15, 1982
no. fish recovered	89	53	52	50
mean length-in (SD)*	14.09(0.22)	15.48(1.65)	10.43(0.14)	14.96(1.22)
mean weight-lb (SD)*	1.07(0.34)	1.63(0.55)	0.40(0.14)	1.47(0.39)
Culture days	201	153	123	252
Mortality %	39.1	17.2	30.7	2.0
Growth rate in/day	0.036	0.009	0.044	0.018
lb/day	0.005	0.004	0.003	0.004
Feed conversion lb gain/lb fed	0.38	0.27	0.41	0.59

* SD = standard deviation

Table 5. Mean condition factors, and ranges for redband trout cultured in earthen ponds and indoor circular tanks at Heart of the Hills Research Station, Ingram, Texas, November, 1981-November, 1982.

Culture unit	Condition factor ($x 10^{-7}$)	Range
Pond A	3854.49	3685.26 - 4227.21
Cement tank	3776.00	3205.08 - 4394.69
Pond B	3693.55	3539.66 - 3898.07
Fiberglass tank	3871.80	3569.06 - 4387.02

Neb,

Mc Conaughy compared w/ domestic

time of year

Lethal Temp. tol. = 50% survive one week. >26 <28

ca. 27° 54 49 = 82° (80-82° ...)

Domestic 25° -- 77° } as Dickson, Kraeur found
56

- Upper Lethal limit -

.5°C /day, ~ .

to 27.7

55. 82 80-82 5 days.

- BLM rept - cite -

Swamp Ck. vs. 3 mi Ck. (Parsnip ...)

OFFICE MEMO

TO: Redband Texas **Date** spawned May 80 – Parsnip Res. Aug. 1981

FROM: Guadalupe R. below Canyon L.

SUBJECT: Hatchery at Mth. Home recvd. Harford ~~June 80~~

REMARKS: ca. 15 mi. Kerrville

Al Sonski, Texas Park & Wildlife Dept.
Heart-of-The-Hills Res. Sta., Junction Star Rt. Box 62
Ingram, TX 78025.

Present paper TX AFS chapt Oct.

also has RB fm. Firehole R. → ½° /day – to 27.9° max] LT 50

raise temp .5 °c /day upper lethal limit 27.4 °c
(some to 27.7)

2 8.3 83

82

80 =

26.5 = 53 -

= 72 hrs

.5 -> 80 °F

27.0

27.5

* - Benfey, T. J. & A. M. Sutterlin. 1984. Triploidy induced by heat shock and hydrostatic pressure in landlocked Atlantic salmon (Salmo salar L.). Aquaculture 36(4): 359-367 - 5 min. 32 °c or pressure shock w/in 20 min fertiliz. = 100% triploids. - w/ 70%-90% survival of controls.

* - Cunjak, R. A. & G. M. Green. 1983. Habitat utilization by brook char (S. f.) and rainbow trout (S. g.) in Newfoundland streams. Can. J. Zool. 61(6): 1214-1219.

* p.22: Burton & Idler 1984. Can landlocked salmon adapt to seawater? J. Fish Biol. 24(1) - ~~no~~ so good. <u>fewer chloride cells</u>

OFFICE MEMO

TO: S 7 A 1984 29(2) **Date**

FROM:

SUBJECT: Sonski, A. J. 1983 (Tex. Parks, Wildl.,

REMARKS: Heart of the Hills. Fish. Res. Station, Ingram 78025)

Culture of redband trout at a warm-water hatchery. Proc. Fish Farm. Conf. Ann. Conv. Fish Farm. TX.

- reared earthen ponds winter & indoor tanks in summer

temp. 49-80°F in ponds, 67-75°F in tanks

in ponds, fish grew from $\bar{x}$ 5.9 in. to 12.3 in - after oversummer
(.08 lb) (.74 lb.)

indoors $\bar{x}$ 15.2 in, 1.55 lb. - survival 65% ponds, 90% tanks

no disease problems.

+ Ann. Proc. TX A.F.S. 5: 66-76 (1983) Heat tolerance of redband trout. - upper lethal limit - acclimate 20°C

THE STATE OF TEXAS

Texas Parks & Wildlife Department
Heart of the Hills Research Sta.
Junction Star Rt., Box 62
Ingram, Texas 78025
RETURN REQUESTED

PM 1983

42

TX redband
temp — NB M'Con not here

Dr. Robert Behnke
Dept. of Fish & Wild. Biology
Colorado State University
Fort Collins, Colorado 80523

copies BLM rept

Feeding temp.
Dwyer et al. to 27
Bozeman (25)