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Effects of Gamma Radiation and Temperature on Growth of Juvenile Rainbow Trout (*Salmo gairdneri*)

Abstract

Effects of gamma radiation and temperature on growth of juvenile rainbow trout (*Salmo gairdneri*) were studied in continuous flow aquaria. Fish fingerlings acclimated to 10°C were exposed to various doses of gamma radiation up to 1,000 RADS and placed into filtered tap water at 10°, 15°, and 20°C. They were reared in one of these water temperatures for four weeks and fed 4 percent of their body weight in commercial fish food once per day. Survivors were weighed weekly and counted daily in the basic experiment.

There were no statistically significant ($P < .05$) effects of temperature, radiation, or temperature-radiation interaction on growth. I concluded that the combined action of gamma radiation less than 1,000 RADS and temperature regimes studied did not noticeably affect growth of juvenile rainbow trout within the first four weeks.

Introduction

The objective was to determine the effects of a sublethal dose of gamma radiation and a sublethal temperature shock upon growth of juvenile rainbow trout (*Salmo gairdneri*). Primary emphasis was on the possible synergistic effects of these two variables.

Many studies on effects of radiation and temperature on fish have been published (for example, Gros *et al.*, 1958; Egami *et al.*, 1967; Etoh and Egami, 1967; Egami, 1969). None of these include the combined effects from sublethal doses of gamma radiation and a temperature shock.

Methods and Materials

Juvenile rainbow trout (*Salmo gairdneri*) were obtained from Troutlodge Springs Fish Hatchery near Soap Lake, Washington. Initial range of lengths and weights for the various replicates was variable (Table 1). Hatchery incubation temperature for all test fish was 10°C, and the total hardness (as CaCO₃) of the hatchery water was 120 ppm.

TABLE 1. Range of initial lengths and weights of juvenile rainbow trout (*Salmo gairdneri*).

Replicate	Date of Purchase	Length ^a (mm)	Weight (gms)
1	October 20	52-89	1.4-8.4
2	November 27	34-55	0.2-1.7
3	January 15	58-83	1.1-6.5
4	February 16	65-92	2.0-9.3

^a The largest fish in any one test container within a trough was initially no longer than 1 1/2 times the shortest. All fish were of 0 age group, *i.e.*, less than 1 year old.

Continuous flow bioassay was used as the test procedure (Edmundson, 1971). Minimum water flow was 5 L/gm of fish per day. A hardness of 160 ppm, D. O. con-

centration from 8 to 10 ppm, pH of 7.5, and a copper concentration of 0.008 ppm or less were measured in the test water.

Each group, consisting of 10 fish each, was exposed to a 17,000 Ci⁶⁰Co source at 10 or 11 R/sec to obtain approximate whole body acute gamma radiation doses of either 0, 320, 560, 870, or 1,000 RADS. Water temperature prior to and during radiation was 10°C. All radiation exposures were done between 3:30 and 5:00 pm. Within 30 sec after irradiation, I placed the fish into a test chamber containing either 10°, 15°, or 20°C water. Therefore, fish placed in 15°C water received an immediate temperature change of 5°C and those placed in 20°C received a change of 10°C. Fish were left in these temperatures and test containers for the remainder of the four-week experiment. Hereafter, I will refer to those fish that received 0°, 5°, or 10°C temperature change as 10°, 15°, and 20°C fish, respectively. Control fish were treated the same as irradiated fish, except they received no radiation. Fish were fed their hatchery diet of Sterling Silver Cup Fish Food No. 4 in amounts approximately 4 percent of their body wet weight once per day. Initially, the largest fish in a test container was no larger than 1 1/2 times the smallest. Once a week, I anesthetized (using MS 222), measured, and weighed individual fish in each group in the same manner as during initial measuring and weighing.

During all four replicates, all fish were swimming upright before being exposed to gamma radiation and before temperature changes. For further details concerning the procedure see Edmundson (1971).

All experiments were carried out at the Washington State University Nuclear Radiation Center, Pullman, Washington, during October 1970 to March 1971.

Results

The growth of juvenile rainbow trout was analyzed in two ways: (1) a separate analysis of variance of the average gain or loss in weight each week, and (2) an analysis of variance of the average total gain or loss in weight over the four-week period. Average weights of the fish present in a group were used because some fish died before the experiment was complete, thus complicating the analysis of variance. Weight gained or lost during the first week was computed as the average weight at the end of the first week minus the average initial weight of the group. Weight change for the second week was found by subtracting the average for the end of the second week from that for the end of the first week, and so forth. In referring to particular weeks, I will use week 1, 2, 3, or 4 to indicate the growth during the *i*th week (*i* = 1, 2, 3, 4). The reason for weekly comparisons is that fish which received a certain temperature-radiation combination may show a different functional response through time with the endpoints being similar. As observations among weeks were correlated (*i.e.*, they were the same fish for each group), statistical analysis of growth as a function of time and a single analysis of variance of the set of data were not attempted.

There were no statistically significant ($P < .05$) effects of temperature, radiation, or temperature-radiation interaction observed in any of the analyses (Table 2). Those fish raised in 15° and 20°C water (a temperature change of 5° or 10°C, respectively) averaged over all radiation levels, lost more weight on the average during week 1 than did the 10°C fish, but gained more during the remaining three weeks. Fish in 15°C water increased in final gained weight whereas those in 20°C gained only enough to

TABLE 2. Analysis of variance of the average gain or loss in weight (gm) of juvenile rainbow trout (*Salmo gairdneri*) exposed to acute gamma radiation and a temperature change.

Source of Variation	df	Week								Total	
		1		2		3		4		ms	F
		ms	F	ms	F	ms	F	ms	F		
Main Plot											
Replicates	3	1.449		.575		.586		.607		10.065	
Temperature ^a	2	.154	2.52	.043	2.69	.375	3.04	.282	4.82	1.018	2.12
Main plot error	6	.061		.016		.123		.066		.479	
Subplot											
Radiation ^b	4	.055	2.58	.028	1.41	.040	1.46	.065	1.23	.288	1.86
Radiation x temperature	8	.014	.64	.032	1.63	.008	.29	.052	.99	.086	.70
Subplot error	36	.021		.020		.027		.053		.122	
Total	59										
		F .05 ^(1,6) = 5.99				F .05 ^(4,36) = 2.63					
		F .05 ^(2,6) = 5.14				F .05 ^(8,36) = 2.21					

^a Prior to and during irradiation fish were in 10°C water. After irradiation they were placed in 10°, 15°, or 20°C water for the remainder of the experiment (28 days).

^b Whole body acute gamma radiation levels of 0, 320, 560, 870, and 1,000 R.

replace that amount lost during the four weeks. Largest average growth, \pm one standard deviation, (0.38 ± 0.69 gm) was observed in fish exposed to 15°C water and 320 RADS (Table 3). Lowest average growth was in 10°C fish exposed to either 0 (-0.37 ± 1.23 gm) or 870 RADS (-0.38 ± 1.16 gm). When I considered the average weekly or total growth combining all three temperatures, I found the growth pattern was similar at the different radiation levels. The synergistic relationship of temperature change and acute gamma radiation on average weekly growth and average total growth was not consistent.

TABLE 3. Average total gain or loss (\pm one standard deviation) in weight (gm) of juvenile rainbow trout (*Salmo gairdneri*) exposed to acute gamma radiation and a temperature change.

Radiation (RADS)	Temperature (°C) ^a			Total
	10°	15°	20°	
	$\bar{x} \pm s^b$	$\bar{x} \pm s$	$\bar{x} \pm s$	
0	$-0.37^c \pm 1.23$	0.27 ± 0.68	0.14 ± 0.70	0.01 ± 0.87
320	-0.14 ± 1.42	0.38 ± 0.69	-0.03 ± 0.65	0.07 ± 0.88
560	0.02 ± 0.55	0.27 ± 0.76	0.23 ± 0.79	0.17 ± 0.65
870	-0.38 ± 1.16	0.10 ± 0.85	-0.31 ± 1.06	-0.20 ± 0.96
1000	-0.29 ± 0.96	0.05 ± 1.06	0.20 ± 0.98	-0.01 ± 1.03
Total	-0.23 ± 0.96	0.21 ± 0.74	0.04 ± 0.75	0.01 ± 1.03

^a Prior to and during irradiation fish were in 10°C water. After irradiation they were placed in 10°, 15°, or 20°C water for the remainder of the experiment (28 days).

^b Standard deviations were computed using the individual average total gain or loss in weight for each of the four replicates.

^c Sample size was 40 fish (10 for each replicate) at the start of the experiment.

A comparison of the four replicates showed that average weekly growth pattern for each succeeding replicate was lower than the preceding replicate. Here again may be evidence that experimental control was influenced by the fish allocated to the replicates. However, all fish were gaining weight at the end of the four weeks.

Discussion

The effect of an abrupt 10°C or less temperature change on fish growth was not statistically apparent during the 28 days of this study. No differences were found which could not be explained by the temperature the animal was kept in or the feeding level. Although apparent trends were developing, 28 days did not give adequate time for the effect of combined temperature and radiation to show up.

There was considerable variation in the average growth observed in this experiment. A large amount of this variation apparently can be attributed to the difference in fish size among replicates. The weekly average growth declined during each consecutive replicate, with the lowest in the February-March replicate (replicate 4). At the end of the experiment, however, the fish were gaining weight in all replicates. Decrease in weight may be correlated with the time of first feeding within a replicate. The presence of fecal matter was used as an indication of feeding to see if such a relationship existed. In the first replicate, fecal matter began appearing on the fifth day, in replicates 2 and 3, within the tenth to fourteenth day, and in replicate 4, it was on the sixteenth day. Initial feeding of 10°C fish was usually one to two days after that of the 15° and 20°C fish. This delay in initial feeding time suggests that the physiological condition may not have been the same for the four groups of fish.

To my knowledge, the interaction of an immediate temperature change and radiation on growth of fish has not been reported. Effects of radiation on fish growth have been studied, but usually at varying temperatures. Bonham *et al.* (1948) stated that the effect of X-radiation on the growth of chinook salmon fingerlings during 12 weeks was generally directly related to the amount of X-rays received. The average weight of fish exposed to 250 R or less was not statistically different from the controls ($P \leq .05$), whereas groups receiving 500 R or more weighed less and the difference increased after four weeks. Welander *et al.* (1948) stated that differences in average weights of chinook salmon egged fry exposed to X-rays of 1,000 R were "doubtfully different" from 0 R through the sixty-fifth day. After 125 days, those salmon exposed to 1,000 R weighed 45 percent less than controls. No significant differences were observed in the final average weights of fish exposed to 500 R or less when compared to controls.

Yearling rainbow trout fed 0.5 uCi of Strontium-90-Yttrium-90 per gram of tissue per day began to weigh less on the average after 12 weeks, as compared to controls; however, there was no statistical difference from the controls in those fed 0.05 uCi (Nakatani and Foster, 1963). Purdom (1966) reports that exposure of 500 or 1,000 R of X-rays to six-week old guppies (*Lebistes reticulatus*) did not affect lengths of the fish during the following eight weeks. One disadvantage of a four-week test is that during experiments which serve to place considerable stress on the fish, long-term growth effects may not be detectable. There is evidence in the literature, however, that growth responses to temperature can appear within four weeks (Banks *et al.*, 1971; Brett *et al.*, 1969).

In my experiment, there were indications of possible growth stimulating effects of radiation and temperature. Although not statistically significant, fish which received

320 or 560 RADS had greater average final growth when compared with those of other radiation levels and controls. The highest final growth was 320 RADS in 15°C water. This figure does not seem uncommon, since 15°C is near the optimum temperature for rainbow trout (Garside and Tait, 1958).

I did find, however, that fish exposed to 10°C and 0 RADS had the lowest growth of any group. One would think that these "control" fish would at least maintain their present weight. Since these fish were treated exactly the same as the other test fish, I can only conclude that stress of handling had an adverse impact.

The presence of a somewhat higher growth and survival of animals at low radiation levels has been reported before (Lorenz *et al.*, 1954; Carlson *et al.*, 1957; Carlson and Jackson, 1959; Marshall, 1963; Atlan, 1968; Wadley and Welander, 1971). Further research should be conducted testing the impact of temperature change and sublethal radiation over longer periods of time and during different times of the year.

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