MICHIGAN DEPARTMENT OF CONSERVATION
Research and Development Report No. 150*

October 15, 1968

GROWTH RATES OF COHO SALMON AND STEELHEAD TROUT WITH A LIMITED FOOD SUPPLY[1]

By Percy W. Laarman

Abstract

Competition between coho salmon and steelhead trout was studied by comparing specific growth rates of the two species in a laboratory raceway. The raceway was partitioned into six test compartments, each 5 feet long by 14 inches wide; each compartment had flowing water of about 45 gallons per minute with temperature averaging 57 F and dissolved oxygen 6.5 ppm. Fingerling salmon and trout of similar size were compared, and tests were run on fingerlings 2.3 to 3.0 inches in length and also on fingerlings 3.6 to 4.1 inches long. The fish were fed the Oregon moist pellet from 5 October to 20 December 1967. Daily feeding rates were kept below optimum and ranged from 1.8% to 3.6% of body weight. When trout and salmon below 3.3 inches were held together in the same raceway, the trout grew at a significantly faster rate; in other words steelhead trout were dominant over coho salmon in utilizing food from a limited supply. Above 3.3 inches the growth rate of the experimental trout was also greater than that of the salmon, although the difference was not significant at the 95% confidence level. Specific growth rates were dependent on the initial sizes of the fish.

* Institute for Fisheries Research Report No. 1749.

1 A contribution from Dingell-Johnson Project F-31-R.

Introduction

The introduction of coho salmon, Oncorhynchus kisutch (Walbaum), into Michigan waters presents many questions and problems for fish management. One of these problem areas is the competition for food that may exist between fingerling coho salmon and native trout in streams. The purpose of these experiments was to investigate possible competition between coho salmon and rainbow trout, Salmo gairdneri Richardson, by comparing growth rates of the two species held under partially controlled conditions.

In a preliminary study during April and May, 1967, I studied competition between coho salmon and rainbow trout by comparing growth of the two species when held together in a laboratory raceway. The rainbow trout were from hatchery brood stock. Unfortunately the facilities necessitated holding the control fish at a date immediately following rather than concurrently with the experimental fish. The fish about 5 inches long were fed for 28 days at the daily rate of 2.5% of body weight. The rainbow controls, rainbow experimentals, and coho controls increased in weight an average of 8.1, 8.4 and 4.1 grams respectively. Coho experimentals lost an average of 1 gram per fish.

The conclusion drawn from the preliminary study was that rainbow trout were dominant over coho salmon in getting food. A critical review of the preliminary study led to the present revised experiment in which the controls were run concurrently with the experimentals, the hatchery stock of rainbows was replaced with steelhead (offspring from a Great Lakes spawning run), and size of the salmonids used was 2 to 4 inches rather than 5 inches.

Methods

Facilities at the Saline Fisheries Research Station, Saline, Michigan, were used. One metal tank (15 feet long by 28 inches wide and 28 inches high) was partitioned lengthwise to provide two identical compartments. Each compartment was further subdivided with 0.25-inch hardware cloth into three areas of equal size thus making six compartments for holding fish (Fig. 1). Screens were placed 1 foot from each end of the tank for water intake and discharge pools. A pump rated at 90 gallons per minute circulated the water through the compartments. In addition a small flow of aerated well water was constantly added to the intake pool. Water level was held constant with a standpipe in the discharge pool. The bottom of the tank was covered with coarse gravel. Thickness of the gravel varied, which resulted in water depths ranging from 2 to 13 inches in each compartment. Water temperatures were monitored with a constant recording electrical thermograph. The water temperatures ranged from 54 to 59 F with an average of 56.9 F. Dissolved oxygen was 6.5 ppm.

The trout were an F_1 generation from steelheads collected during a Great Lakes spawning run. Prior to the study both species of fish had been held at rearing station facilities. The fish were acclimated to tank conditions for 15 days before starting the experiment. The experiment began on 5 October 1967 and was concluded on 20 December 1967. During the course of the experiment the fish were weighed and measured on 30 October and 26 November. The fish were assigned to the six test compartments as follows: A = coho control, B = coho vs steelhead experimental, C = steelhead control, D = coho control, E = steelhead control, and F = coho vs steelhead experimental (Fig. 1). Each control group consisted of 24 fish. The two experimental groups each contained 12 steelhead and 12 salmon.

The Oregon moist pellet (Hublou, 1963) was fed twice daily at irregular hours. Daily feeding rates were as follows: 2- to 3-inch fish received 3.6% of body weight, 3- to 4-inch fish received 2.8% of body weight, and 4- to 5-inch fish received 2.1% of body weight. These different rates were used for the various inch groups to compensate for the higher maintenance requirements of smaller fishes. These rates were below what is necessary for maximum growth at 57 F water temperature. On 30 October, the daily rations were adjusted to compensate for the average growth changes in each group of fish. Again on 26 November adjustments for growth were made in the daily feeding rates; also, on this date, an additional 15% reduction in the feeding rates was made to induce greater competition for food.

Results

Average lengths and weights of each group of fish at the beginning and end of the experiment are shown (Table 1). At the beginning of the experiment, the fish in each compartment were selected for uniformity in length as closely as possible to eliminate competitive advantages due to size. Ranges in length varied from 0.4 inch to 0.6 inch within compartments. At the end of the experiment these ranges had increased from a low of 0.6 inch to 2.0 inches.

Growth was measured by determining the mean specific growth rate for each group of fish. In the experimental compartments growth was determined separately for the two species. Specific growth rates were calculated from the formula

$$G = \frac{\log_e Y_T - \log_e Y_t}{T - t} \times 100,$$

where G = specific growth rate, Y_T = weight at time T, Y_t = weight at time t, and T is later than t. Time is expressed as 10-day periods, and the specific growth rate is an instantaneous rate per time period expressed as a percentage. Since the calculation of G takes into account both initial and final sizes, it is useful in comparing growth of different size fish (Brown, 1957).

The mean specific growth rates decreased with time for each group of fish (Table 2). Water temperatures fluctuated very little and feeding rates remained constant from 5 October to 26 November; therefore these factors can be eliminated as factors contributing to the decreased growth rate. The natural decrease in daylight hours during this time period may have contributed to the decreased growth rates. A responsible factor may have been the physiological cycle discussed by Brown (1946). The continued decrease in growth rates from 27 November to 20 December was expected, since feeding rates were reduced by 15%. All groups except one continued to gain weight during the experiment indicating that feeding rates were above body maintenance requirements. The group containing the largest coho experimentals showed a negative specific growth rate of 1.11 from 27 November to 20 December.

There was an inverse relationship between size of fish and specific growth rates. This relationship was analyzed by comparing growth of fish 3 inches and less with growth of fish over 3 inches, by the student-t test. Results showed a significant difference in specific growth rates-- $t = 3.09$, d.f. $= 6$. Regardless of species or interspecific competition, the growth rates were significantly greater for smaller fish than for larger fish.

Results of the preliminary study mentioned earlier in this paper indicated that growth rates should be compared between experimental fish and controls. Also growth rates between species should be analyzed. If steelhead were dominant over coho, then the steelhead experimental fish would show the fastest growth rate and coho experimentals the slowest growth rate. Growth rates of the control fish would be expected to be intermediate. These comparisons were made by the regression of individual fish lengths on mean specific growth rates with 95% confidence limits (Snedecor, 1956). The steelhead experimental fish grew faster than all other fish of comparable size. Growth of the largest coho experimentals was slowest, and the remainder of the fish grew at intermediate rates (Fig. 2). To test the hypothesis that the environment was suitable for similar growth rates of both species, a comparison between control groups of coho and steelhead was made. There was no significant difference between control groups of the two species that were 2.8 inches and larger (Fig. 3). From this statistic the assumption is valid that the environment of the experimental tank was suitable for similar growth rates of both species in the size ranges used for experimental fish. One exception was in compartment F where the initial average length of the steelheads was 2.6 inches. These fish could be expected to grow faster until reaching 2.8 inches. In reality there was little difference in the growth rates of the two species until all fish in compartment F had reached 2.8 inches.

Steelhead experimental fish below 2.9 inches grew significantly faster than steelhead controls of similar size (Fig. 4). Although the difference in growth of the largest steelhead controls and largest steelhead experimentals was not significant the controls grew at twice the rate of the experimentals. The difference in specific growth rates between coho control and coho experimental fish was not significant (Fig. 5).

The specific growth rates of the steelhead experimental fish were significantly greater than the coho experimentals at lengths below 3.3 inches (Fig. 6). Above 3.3 inches the confidence limits overlap slightly. Even though the difference is not significant above 3.3 inches, I feel that the steelhead in compartment B had an advantage over the coho in the same compartment. My reason is that the average specific growth rate of the steelheads was over 3.5 times that of the coho. In addition the coho in compartment B were the only group to show a negative specific growth rate at any time.

From the data presented it appears that fingerling steelhead trout have an advantage over coho salmon in competing for a limited food supply. The advantage seems to be greatest at the smaller sizes. The factors responsible for this advantage are not clear from this experiment. Since the environment was suitable for growth rates of similar magnitude for control groups of both species, behavioral characteristics must be important. Observations on behavior were made only during feeding time. Salmon appeared to feed at the surface more readily than the steelheads. The trout fed more vigorously after food began sinking below the surface. This was observed only with the control groups, since the species could not be distinguished in the experimental compartments. Hartman (1965) found that, under partially controlled conditions in winter, coho and steelhead trout occupied different positions in an experimental pool that was comparable to a natural pool; the coho formed groups in open water above bottom, whereas trout scattered across the bottom. If this position were maintained during feeding, then the trout would have the advantage in picking food off the bottom.

Mortality was not an important factor in this experiment. Three steelhead control fish died early in the study, and there was no coho mortality.

Conclusions drawn from this study are twofold: (1) the growth rates of the two species were dependent on the initial size of the fish, and (2) interspecific competition for a limited food supply resulted in steelhead trout being dominant over coho salmon.

Acknowledgments

Floyd E. Simonis assisted in construction of the recirculating unit and fed the fish. Statistical assistance was provided by James R. Ryckman. Gerald P. Cooper, William C. Latta and James W. Merna reviewed the manuscript. Dan Vokovich prepared the figures.

INSTITUTE FOR FISHERIES RESEARCH

Percy W. Laarman

Report approved by G. P. Cooper

Typed by M. S. McClure

Literature cited

Brown, Margaret E. 1946. The growth of brown trout *Salmo trutta* Linn. II. The growth of two-year-old trout at a constant temperature of 11.5° C. J. Exptl. Biol., 22: 130-144.

Brown, Margaret E. 1957. The physiology of fishes. Vol. I. Metabolism. Academic Press, Inc., New York, 447 p.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon *Oncorhynchus kisutch* and steelhead trout *Salmo gairdneri*. J. Fish. Res. Bd. Canada, 22(4): 1035-1081.

Hublou, W. F. 1963. Oregon pellets. The Prog. Fish-Cult., 25: 175-180.

Snedecor, George W. 1956. Statistical methods. 5th ed. Iowa State College Press, Ames, Iowa, 534 p.

Table 1.--Mean size of fish at the beginning and end of experiment. Range for lengths and weights in parentheses.

Group	Number of fish	Mean length (inches)		Mean weight (grams)	
		5 Oct.	20 Dec.	5 Oct.	20 Dec.
A Coho control	24	3.0 (2.9-3.3)	3.9 (3.1-4.8)	4.9 (2.7-7.4)	9.7 (4.8-19.5)
B Coho experimental	12	3.8 (3.6-4.1)	4.0 (3.7-4.4)	8.3 (6.9-9.9)	9.8 (7.5-13.1)
B Steelhead experimental	12	3.9 (3.7-4.1)	4.6 (4.1-5.7)	9.3 (7.6-10.1)	17.0 (10.0-32.0)
C Steelhead control	24[a]	4.1 (3.8-4.4)	4.4 (3.8-5.4)	10.1 (6.5-14.6)	13.4 (7.4-25.4)
D Coho control	24	3.6 (3.4-4.0)	4.2 (3.5-5.4)	7.2 (5.4-10.6)	12.0 (6.1-25.2)
E Steelhead control	24[b]	2.3 (2.1-2.6)	3.5 (2.9-4.4)	2.4 (1.3-4.0)	7.5 (4.0-13.4)
F Coho experimental	12	2.8 (2.6-3.0)	3.7 (3.4-4.2)	3.7 (2.8-5.0)	8.4 (6.2-11.6)
F Steelhead experimental	12	2.6 (2.4-3.0)	4.0 (3.6-4.4)	3.1 (1.8-5.9)	11.1 (7.5-14.4)

[a] Two fish died during the experiment.

[b] One fish died during the experiment.

Table 2.--Mean specific growth rates of fish, expressed as per cent weight change per 10 days. Mean length (inches) of fish at beginning of experiment (5 October) is given in parentheses.

Group	Date: 5 Oct. - 30 Oct.	Date: 31 Oct. - 26 Nov.	Date: 27 Nov. - 20 Dec.	Weighted mean[a]
E				
Steelhead control (2.3)	23.16	15.38	5.82	15.02
F				
Coho experimental (2.8)	21.13	6.69	3.68	10.62
Steelhead experimental (2.6)	23.60	15.35	9.61	16.33
A				
Coho control (3.0)	15.43	6.72	3.64	8.70
D				
Coho control (3.6)	11.46	5.52	2.53	6.59
B				
Coho experimental (3.8)	6.71	0.85	-1.11	2.21
Steelhead experimental (3.9)	12.07	7.71	3.30	7.80
C				
Steelhead control (4.1)	6.06	4.34	0.33	3.67

[a] Weighted according to number of days in the three periods.

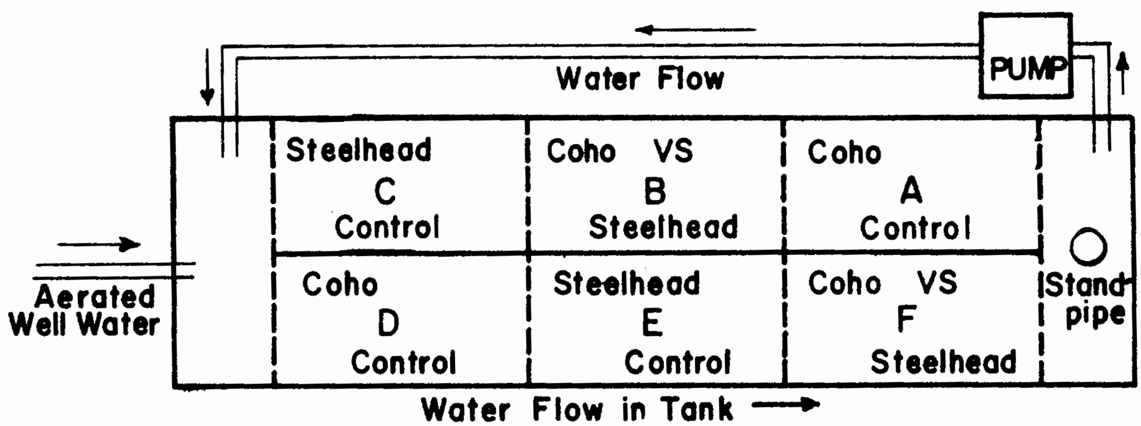

Figure 1.--Diagram of recirculating system in tank with assigned compartments.

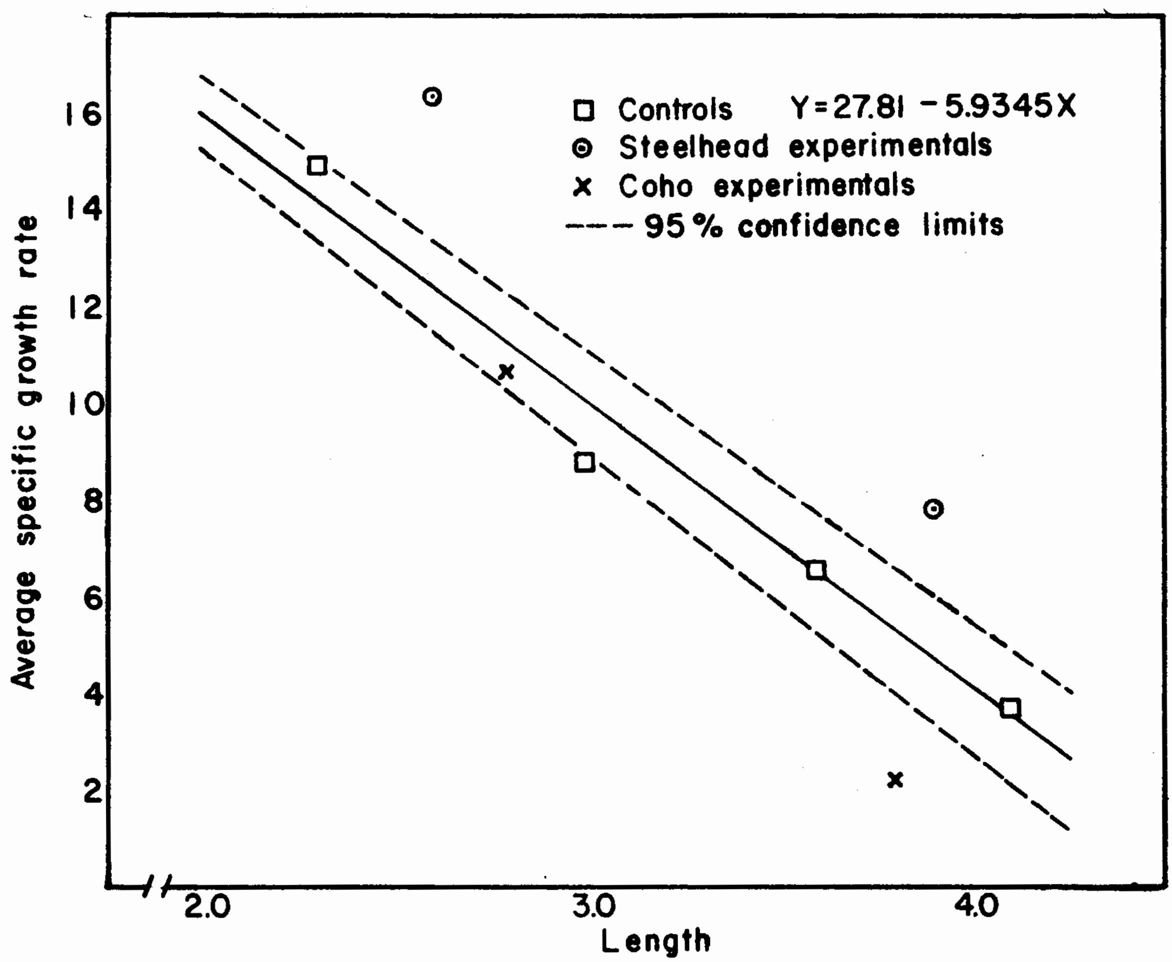

Figure 2. --Regression of average specific growth (expressed as per cent per 10 days) of controls on length of fish in inches.

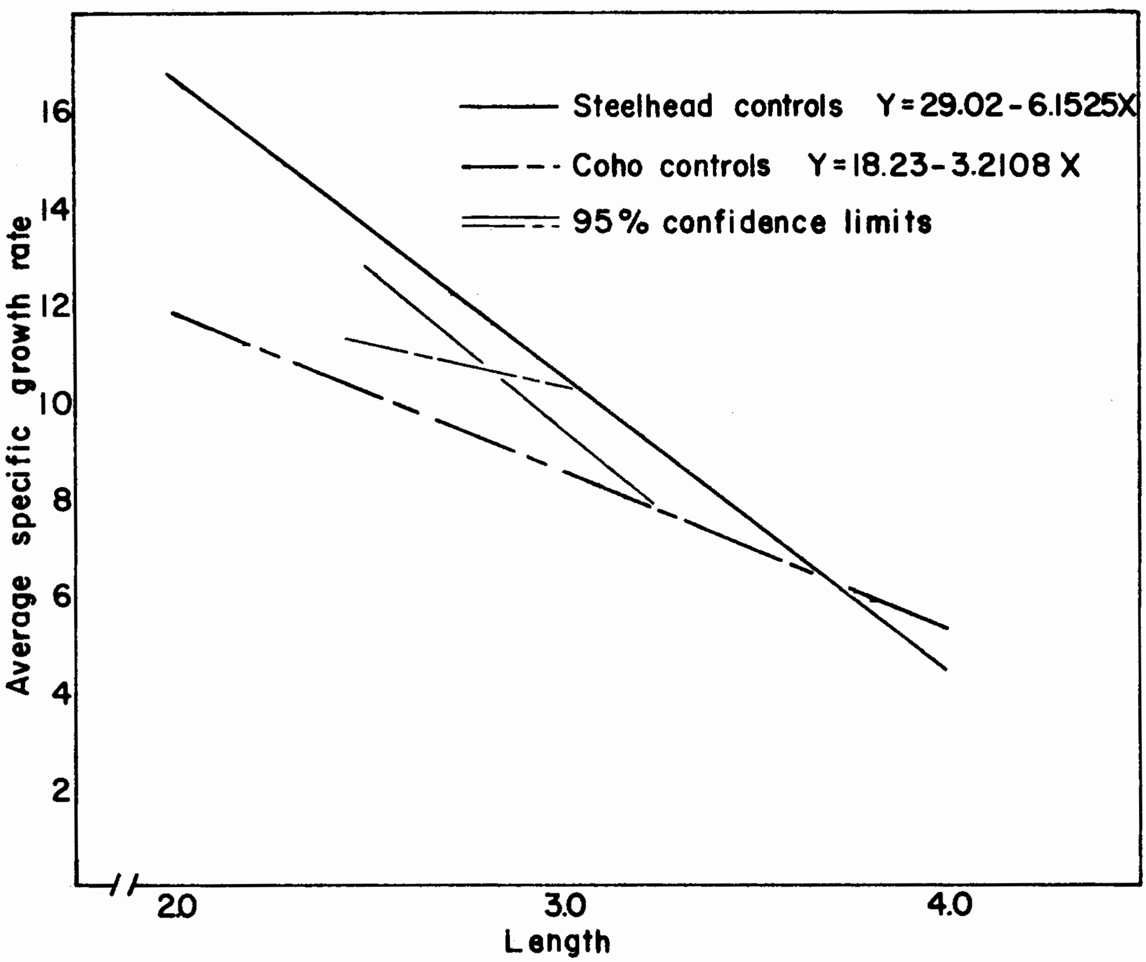

Figure 3. --Regression of average specific growth (expressed as per cent per 10 days) on total length of fish in inches. Steelhead controls vs coho controls.

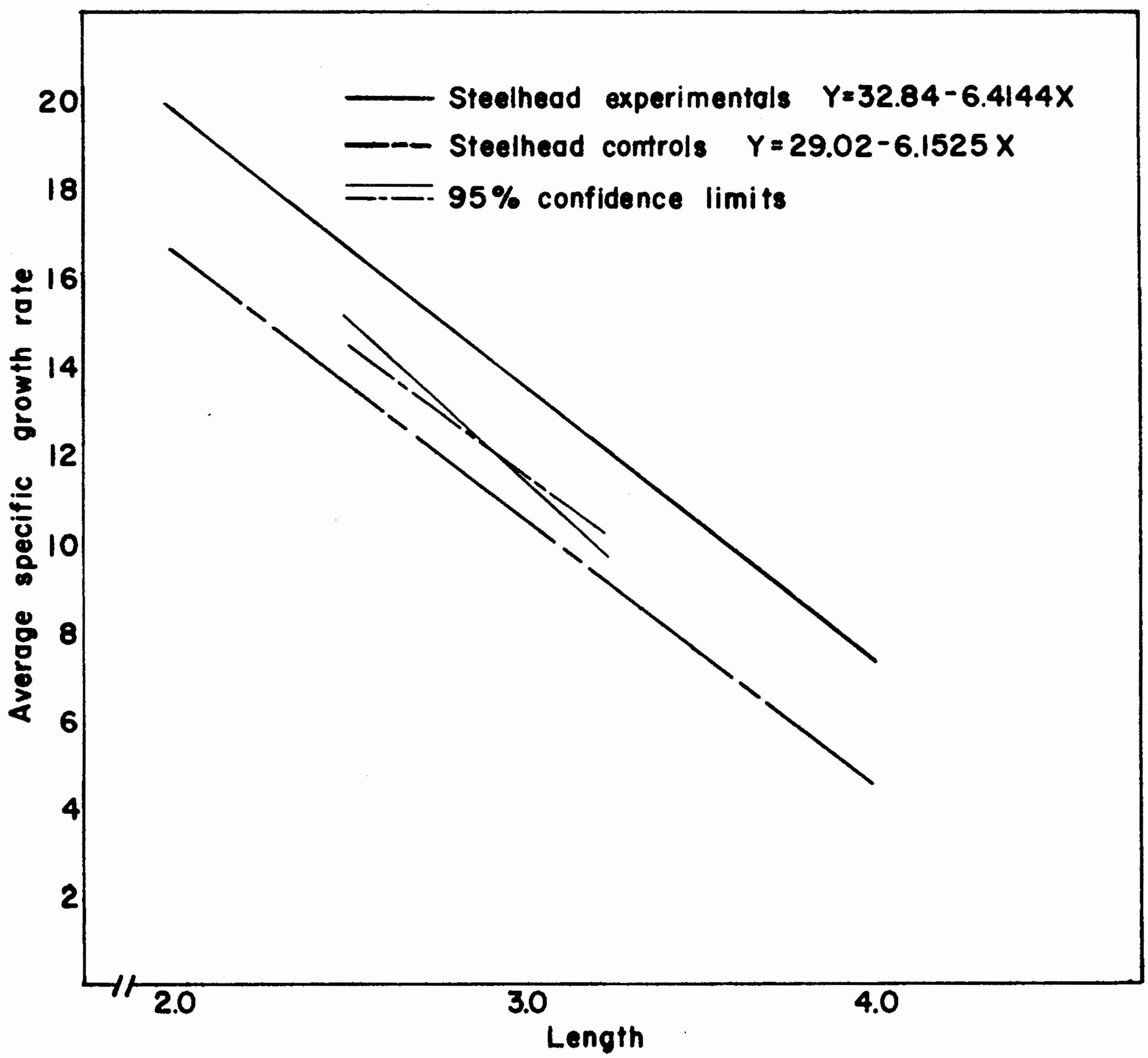

Figure 4.--Regression of average specific growth (expressed as per cent per 10 days) on total length of fish in inches. Steelhead controls vs steelhead experimentals.

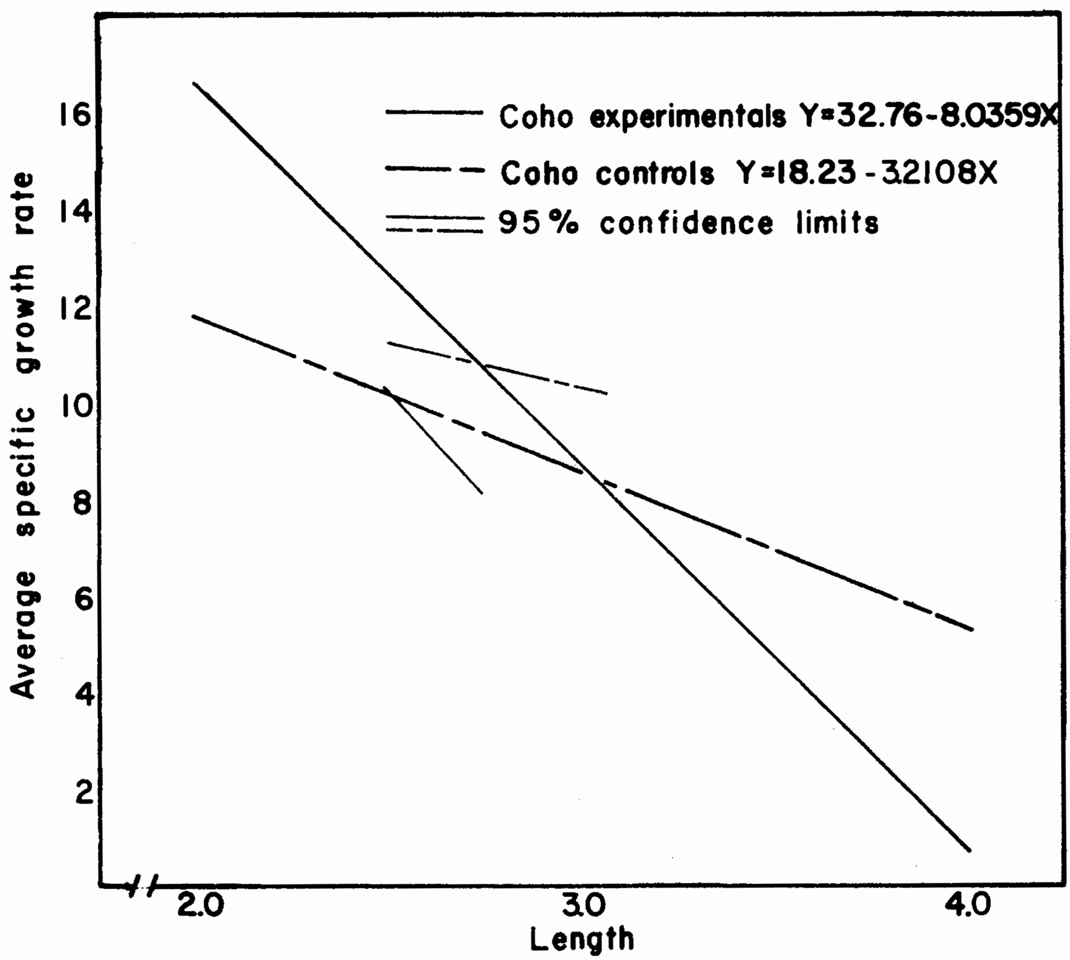

Figure 5.--Regression of average specific growth (expressed as per cent per 10 days) on total length of fish in inches. Coho controls vs coho experimentals.

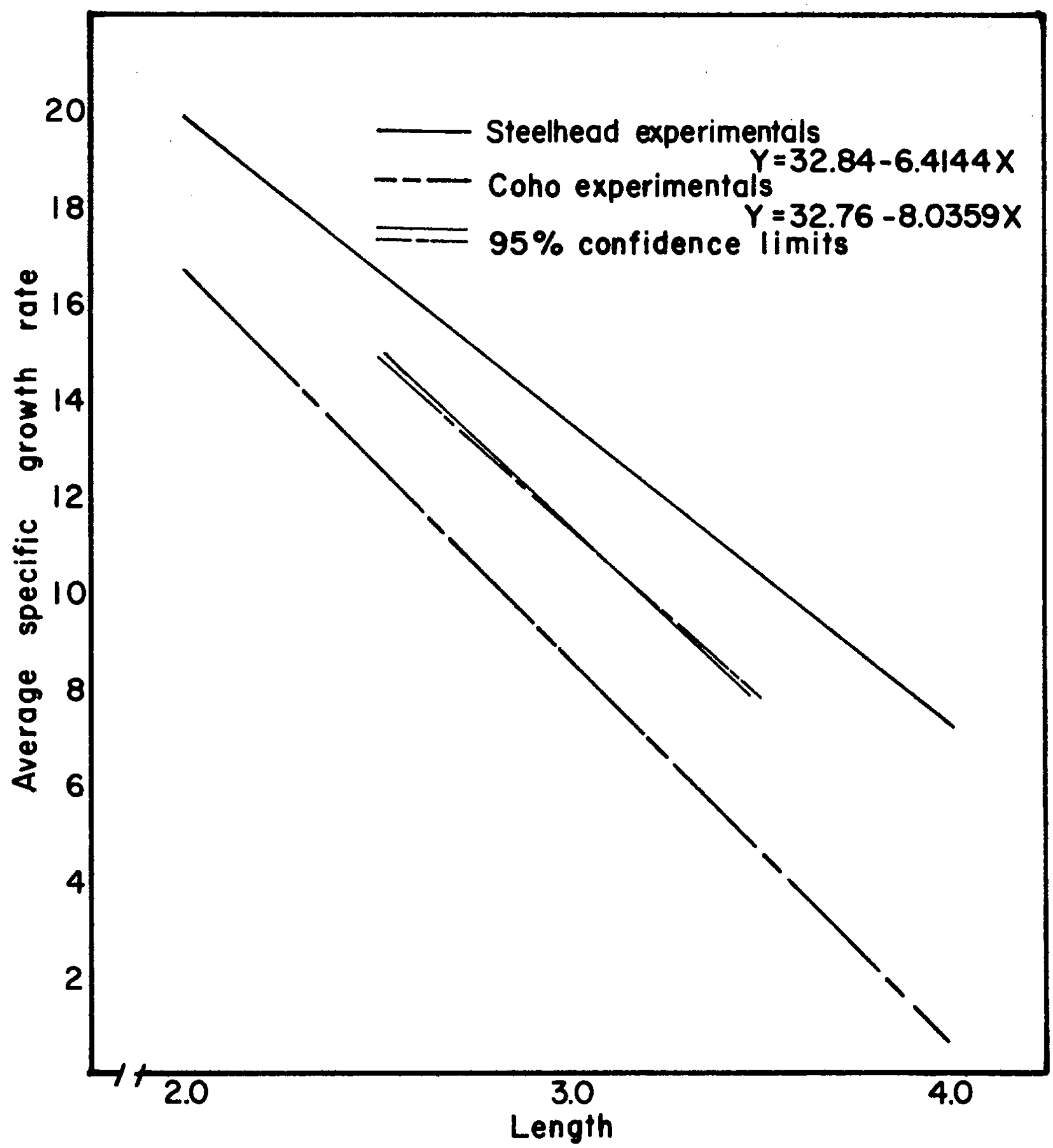

Figure 6. --Regression of average specific growth (expressed as per cent per 10 days) on total length of fish in inches. Steelhead experimentals vs coho experimentals.