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SUMMARY

Growth of channel catfish (*Ictalurus punctatus*) and *Tilapia zillii* in the RRGT geothermal waters can equal or surpass that in a commercial aquaculture facility. Fish and prawn mortality over the course of the intermediate term preliminary study did not appear to be related to any inherent geothermal water chemistry conditions. Temperature control was a problem but does not appear to be beyond design control. The absence of temperature-related mortality in channel catfish, *Tilapia zillii*, and yellow perch (*Perca flavescens*) indicates increased survival and suggests reduced expenditures for disease control. It may also allow higher fish densities in commercial aquaculture operations using geothermal water.

Results of this study indicate potential for commercial aquaculture development at the Raft River Geothermal Testing Site. Longer term studies are warranted.

In June of 1976, the Energy Research and Development Administration (ERDA) entered into a contract with Idaho State University to investigate the potential for commercial aquaculture at the existing Raft River Geothermal Testing Site (RRGT) located in south-central Idaho (see Fig. A). Our purposes were to evaluate: 1) the acute toxicity of geothermal waters to channel catfish (Ictalurus punctatus), Tilapia zillii, yellow perch (Perca flavescens), and the Malaysian prawn (Macrobrachium rosenbergii), 2) growth and long-term toxicity of waters at the Raft River site, and 3) tissue residues of potential contaminants of geothermal origin. Analyses of toxicity, growth and tissue residues in fish and prawns have been completed. Data are still being generated concerning long-term toxicity (section II) and will be submitted as results become available.

I. Acute Toxicity: Bioassays and Mortality.

A. Methods and Materials

Channel catfish and tilapia for this study were supplied by Fish Breeders, Inc. of Buhl, Idaho. Fish, serving as controls were maintained at this commercial aquaculture facility. Yellow perch were obtained from American Falls Reservoir and Oneida Reservoir in southeast Idaho. Malaysian prawns were supplied by Hawaii Fish and Game located in Hawaii.

Fish bioassays were conducted using 72-hour, static tests at 23± 2 C with 100% (full strength), 75% and 50% geothermal water. This was followed by an additional 48-hour test with food to determine if normal feeding behavior would occur. Fish were acclimated to laboratory conditions for 7 days in freshwater prior to initiating the bioassay. They were fed twice daily until 24-hours before the test. Food was withheld during the test to reduce metabolite build-up. Three replicates were used at each concentration of geothermal water. All tanks received aeration from compressors during the bioassay. Spray filtration pumps and compressors were used during the remainder of laboratory confinement. Behavior and water temperature were recorded every 15 minutes for the first hour after introduction of the fish into the test water. Subsequent observations were made hourly for the next 3 hours, at the end of 8 hours and each 12 hours thereafter until termination of the test. Mortality (death) was characterized by the absence of opercular movement.

The prawn bioassay was conducted similarly with the following modifications: 1) concentrations of 100% (full strength) and 50% geothermal water only, and 2) the test was conducted for two 96-hour periods; the first a static test without food the second with food.

B. Results

1. Channel Catfish. No mortality was experienced.

2. Tilapia. No mortality was experienced.

3. Yellow Perch. Two attempts to maintain perch in freshwater in the laboratory produced 100% mortality; therefore, bioassays were not performed. A third group of perch was taken directly from Oneida Reservoir, on the Bear River (Idaho) to the Raft River Site. These perch were exposed to geothermal water on 29 September. They experienced

no mortality until 11 October, when failure of temperature control systems produced 100% mortality. Further studies with this species were suspended.

4. Malaysian prawns. No mortality was experienced.

II. Growth and Long-term Toxicity

A. Growth

1. Methods and Materials

Growth studies with fish were conducted at 28 C (82 F) although temperature control problems existed (see below). Two flow rates, 7 gpm (gallons per minute) (10 minute turnover time) and 0.8 gpm (90 minute turnover time) were used. Stocking densities were 50 fish per raceway (2' x 8' x 16" -- equivalent to 350,000 fish per hectare). Catfish and perch were fed 5% of their body weight per day at dawn and dusk feedings (0700 and 1900, respectively). Tilapia were fed at 3% of body weight until the fourth week. The feeding ratio was then increased to 5% to more closely approximate that of the control facility. Fingerling catfish (average weight 16.16 g and standard length 100.96 mm) and juvenile tilapia (average weight 6.71 g and standard length 53.34 mm) were introduced to the test facility on 20 August. The experimental period extended to 3 December, 1976.

Prawns (50-day post-larvae) were maintained at the RRGT at 4 experimental densities for 50 days (10 October to 29 November, 1976). These prawns were held in four raceways (1' x 8' x 1') which were to have been receiving a constant flow (0.8 gpm) of 27 C (80 F) geothermal water. However, variations in flow rates between raceways (0.04, 0.31, 0.11, and 0.52 gpm in #1, 2, 3, and 4, respectively) occurred. Stocking densities were 12 (1.5/sq. ft.). 24 (3.0/ sq. ft.), 48 (6.0/sq. ft.), and 96 (12.0/sq. ft.), for raceways #1, 2, 3, and 4 respectively. After stocking all raceways, 126 prawns were placed in a 1500 gallon storage tank. Temperature was maintained at 28 C (82 F) with a 400 w emergent heater. There was no water flow and water was only added to replace that lost by evaporation. Since "escape cover" is recommended for closed-tank systems to prevent cannibalism (Ling, 1969; Sandifer et al., 1975) a crushed oyster-shell substrate with clusters of large rocks was provided in each raceway.

Initially, raceway temperatures were to have been 28± 2 C for fish and 27± 2 C for prawns. These are the optimum temperature ranges for growth for the species concerned. However, due to engineering problems this was not acheived. Temperature regimes for both high and low flow raceways are presented in Table 4 and Figures 4.1 and 4.2.

At the time of stocking and at 2-week intervals, the following gross measurements were made on fish: standard length (to nearest millimeter), body depth for tilapia only, and weight (to nearest 0.1 gram). Measurements were taken at monthly intervals from tilapia and catfish stocks at the Buhl commercial hatchery. Prawn measurements were taken at 10-day intervals and were based on a subsample of 10 animals. The length recorded was from the orbit of the eye to the tip of the telson after straightening and gently pinning down each animal on a wet board. Weight was recorded to the nearest 0.1 g.

Growth rate was evaluated for each species. Regression lines were determined for relationships between length and weight, as well as body depth and weight, and growth with time. Regressions were analyzed for significant differences using analysis of covariance (α=0.05). The group comparison "t" test was employed for determining significant differences between group means (α=0.05).

2. Results

a. Channel Catfish. There was no significant difference between growth rates in replicate flow rates at the test site. Growth results are presented in Table 1 and Figure 1. Pooled data revealed no significant difference in growth among experimental and control groups for the first 6 weeks of the study. Pooled data and regressions of growth with time are presented in Table 1.1, Figures 1.2 and 1.3. Loss of temperature control (11 October) accounted for 100% mortality of catfish in the high flow raceways (Table 4 and Figure 4.1). No mortalities were incurred in the low flow raceways. However, subsequent growth of these catfish was significantly less than in controls (Table 1 and 1.1), possibly due to subsequent wide variations in raceway temperatures (Table 4 and Figure 4.2). These samples were also characterized by a sharp decline in condition factor (Figure 1).

b. Tilapia. Tilapia growth in all experimental groups was significantly more rapid at the RRGT than at the Buhl commercial facility. This may be attributed in part to more crowded conditions at the control site. Growth results are presented in Table 2 and 2.1. A significant difference in growth rate existed between high flow replicates, raceways 3B and 3D (there was no significant difference between low flow replicates). Fish in 3B were significantly larger than those in 3D throughout the experimental period. As fish in 3B were initially larger, the observed difference in growth rate may be a function of the developmental state rather than due to differences in raceway placement and associated disturbances (see Interim report, pg. 4). However, these latter conditions may also have influenced growth. No significant differences in either length to weight condition factor (K) or body depth to weight (Z) existed among experimental and control fish.

No fish mortality occurred due to water quality (other than those directly attributed to temperature) over the experimental period. Although growth was interrupted during the seventh week, at the time failure of temperature control occurred, growth resumed within 2 weeks and no long term effects were observed. (Figures 4 and 4.1).

c. Malaysian Prawns. Although conditions and feed were not optimal, prawn growth rate was generally uniform. Growth results are presented in Table 3 and Figures 3, 3.1, 3.2, 3.3, and 3.4.

The first mortality was observed 13 days after introduction when 3 of 12 animals in raceway #1 were found dead. On day 30, the entire population of raceway #4 was found dead. No additional mortality was observed until the experiment was terminated on day 50 when the remaining prawns in raceway #1 (9 of 12), 21 of 24 from raceway #2, and 6 of the remaining 36 in raceway #3 were found dead. This may have been due to fungus-growth as discussed below. Final mortality rates for raceways #1, 2, 3, and 4 respectively were: 100%, 87.5%, 37.5%, and 100%.

The different population densities had no apparent effect on mortality. Sandifer et al. (1975) has reported high survival rates (greater than 90%) at densities of 328-656 animals per sq. ft. without escape cover. The high mortality in raceways #1 and 4 may have resulted from water quality problems due to accumulation of food in the substrate and/or temperature fluctuations rather than from exposure to geothermal water. Fungal growth in the substrate was extensive. The substrate contributed to detritus retention and made cleaning operations difficult. The fish food disintegrated rapidly and accumulated on the substrate. Prawns are particle-size selective and will avoid food that falls apart too quickly (Ling, 1969).

The oyster shell substrate may have contributed to the high mortality by increasing carbonate hardness which has also been suggested as a contributing cause of disease. The rock clusters or a more easily cleaned substrate would probably provide adequate escape cover to reduce cannibalism.

There was no indication that the geothermal water would not support prawn growth. Flow rate may have been responsible for the slower growth rate in raceway #1. Also, as all prawns in this raceway were measured at each sampling period, handling may also have been a contributing factor.

It has been reported that a length of 50 mm is an average value for 100 day juveniles. It is at this stage that growth becomes most rapid. The prawns used in this study were 50 day post-larvae and 21 mm in length initially. After 50 days in geothermal waters prawns with a mean length of 40 mm were obtained. Considering the culture conditions (food, temperature fluctuations, and organic accumulation) their growth was not severely depressed. However, prawns held in the water storage reservoir for the same time period were 50-60 mm in length. Ling (1969), the "father" of prawn culture, reported a length of 50 mm in two months, results that are seldom matched in the U.S.A. Reduced growth of this species has been attributed to temperature and food variation, as well as deteriorated genetic stock (Goodwin and Hanson, 1975). Growth at the Raft River Geothermal Testing Site is evaluated as encouraging.

B. Long-Term Toxicity

Several physiological parameters were used as indicators of growth and long term toxicity. Bone development was monitored by measuring collagen content, calcium, phosphorus, and fluoride concentration in vertebral bone. In addition, the serum electrolytes chloride, calcium, and fluoride are being measured to check the fishes ability to maintain a hydromineral balance.

1. Methods and Materials

Six fish of each species from each raceway were sampled biweekly for physiological and residue accumulation studies. Similar samples were collected from the Buhl commercial aquaculture source on a monthly basis.

Collagen content was determined by the method of Flanagan and Nichols (1962) as modified by Wilson and Poe (1974). Bone mineral studies are not yet complete. However, calcium concentration will be determined by atomic absorption spectroscopy; phosphorus, by the method of Fiske and Subbarow as modified and described by Hawk et al. (1954); and fluoride, by the method of Singer and Armstrong (1968). The serum electrolytes calcium, chloride, and fluoride are also being monitored. Only fluoride analyses on catfish have been completed. Calcium and chloride analyses will be completed as soon as mechanical repairs are completed.

2. Results

a. Channel Catfish. No statistical difference existed among the experimental and control groups for collagen deposition for the first eight weeks. Results are presented in Table 5. A significant difference was apparent between those fish in the low flow raceways and the control fish at the termination of the experiment. Since metabolic rate is proportional to temperature, the synthesis of collagen, which comprises 90% of the organic matrix of bone (Merle and Mayer, 1975), may have been interrupted during periods of low temperature. It is possible that calcification and mineralization of bone, which occurs at this developmental state, may have continued. This would yield a lower collagen concentration in the bone and should become apparent as mineral analyses are completed.

Fluoride analysis of whole blood shows that fluoride concentrations reach a fairly high level early in the experimental period (see Table 6, 6.1 and Figure 6). Levels then decrease to an equilibrium as acclimitization occurs.

b. Tilapia. There were no significant differences among experimental and control groups in collagen content during this study. Results are presented in Table 5.1. Preliminary data of blood fluoride concentrations are presented in Table 6.2. No conclusions can be drawn at this time.

c. Malaysian Prawns. Bone collagen analyses are not applicable to invertebrate animals. Serum studies were also suspended due to the difficulty of taking blood from such small organisms. Techniques to accomplish serum analyses are being examined.

III. Tissue Residue Accumulation.

The following heavy metals have been identified in Raft River Geothermal water: Zinc, lead, manganese, copper, mercury, cadmium, and arsenic. Aquaculture in geothermal waters could lead to residue contamination of edible tissue. Therefore, fishes raised in this preliminary study were examined for accumulation of heavy metals.

A. Methods and Materials

Fish were sampled from the RRGT and commercial facility as indicated above (section II). Analyses for heavy metals were performed on lateral muscle tissue.

Zinc, copper, manganese, lead, and cadmium were anlyzed by atomic absorption spectroscopy. Concentrations of zinc, lead, and cadmium were determined using a carbon-rod attachment (Varian, 1975). Copper and manganese concentrations were determined by methods outlined by Varian (1973) and EPA Technology Transfer (1974). Mercury was analyzed using the "vapor-generation technique"(Varian, 1972 and Uthl, et al., 1970). Arsenic analysis was facilitated by the chemical generation of this element as a volatile hydrate (Varian, 1974). Both of these methods are recommended for greater sensitivity at low analyte levels.

B. Results

1. Water Samples. Zinc, mercury, and cadmium were detected in geothermal water samples from the RRGT. Further analysis of these water samples for arsenic, copper, lead, and manganese indicated that their concentrations were less than the detection limits of our techniques. Results are presented in Table 8.

2. Tissue Samples. a. Arsenic, Cadmium, Copper, Lead, Managanese, and Zinc. Analysis of muscle tissue of catfish and tilapia which had not been exposed to geothermal water showed non-detectable levels of these elements. Samples of tissue from both prawns and fish taken 1.5 and 3 months, respectively, after introduction to geothermal water, also showed non-detectable levels of these elements.

b. Mercury. Preliminary analyses on catfish, tilapia, and prawns revealed measurable levels of mercury in fish and shellfish. Catfish and tilapia from the control facility were also found to contain this element. Thus, additional samples were required. Results of preliminary and subsequent analyses are presented in Table 7 and Figure 7.

IV. Conclusions

Although data are still being generated the following conclusions can be drawn:

1. Channel Catfish and Tilapia.

These species can survive in the geothermal waters at the RRGT. Growth was shown to equal or surpass that achieved at a commercial aquaculture facility providing adequate temperature controls exist. Metabolic impairment and long-term toxicity due to water quality is not anticipated to be a problem. Tissue residue accumulation over this intermediate term experiment was not detectable for arsenic, cadmium, copper, lead, manganese, and zinc. Mercury may be accumulated in muscle tissue, however. Previous work by J.C. Kent (pers. comm.) has shown that mercury accumulation and retention are dependent on a number of environmental conditions such as: temperature, hydrogen ion concentration (pH), alkalinity, and hardness. Data collected to date regarding accumulation is inconclusive. A longer term study would yield more definitive results.

2. Malaysian Prawns.

This species is able to survive and grow in the RRGT geothermal waters. Maximum growth was observed in prawns held at a constant temperature. Flow rate, within the limits of this experiment, did not appear to be growth-limiting.

Fig. A. Location of the ERDA Raft River Geothermal Site (RRGT) and the control commercial aquaculture facility at Buhl, Idaho.

FIGURE C

SCHEMATIC DIAGRAM OF RACEWAY PLACEMENT AND DIRECTION OF WATER FLOW AT THE PRESENT FISH FACILITY OF THE ERDA RRGT.

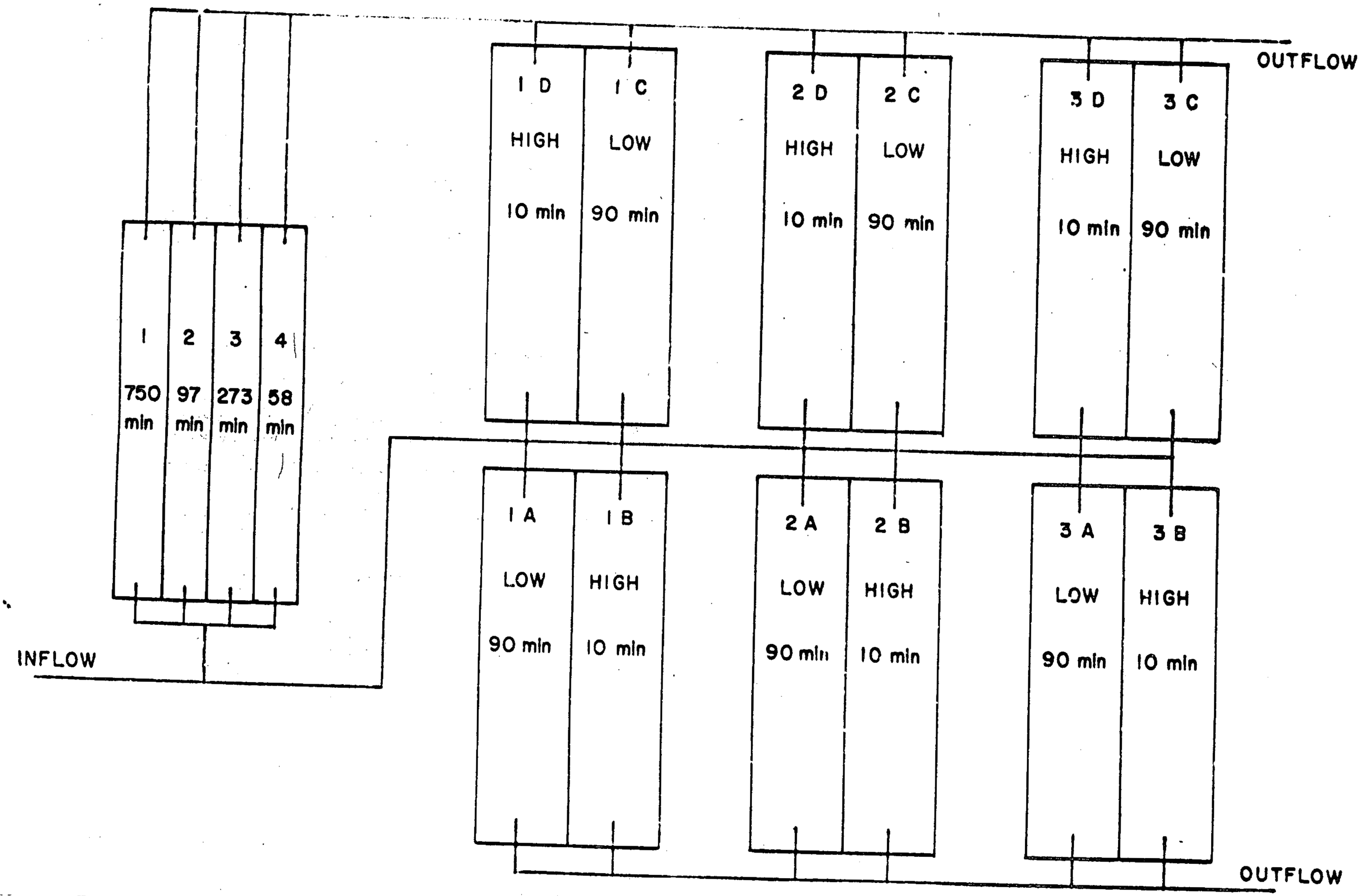


FIGURE 6

SCHEMATIC DIAGRAM OF THE PRESENT FACILITY AT THE RAFT RIVER GEOTHERMAL SITE. WATER FLOW IS INDICATED (ARROWS) AS ARE THE WATER TEMPERATURES.

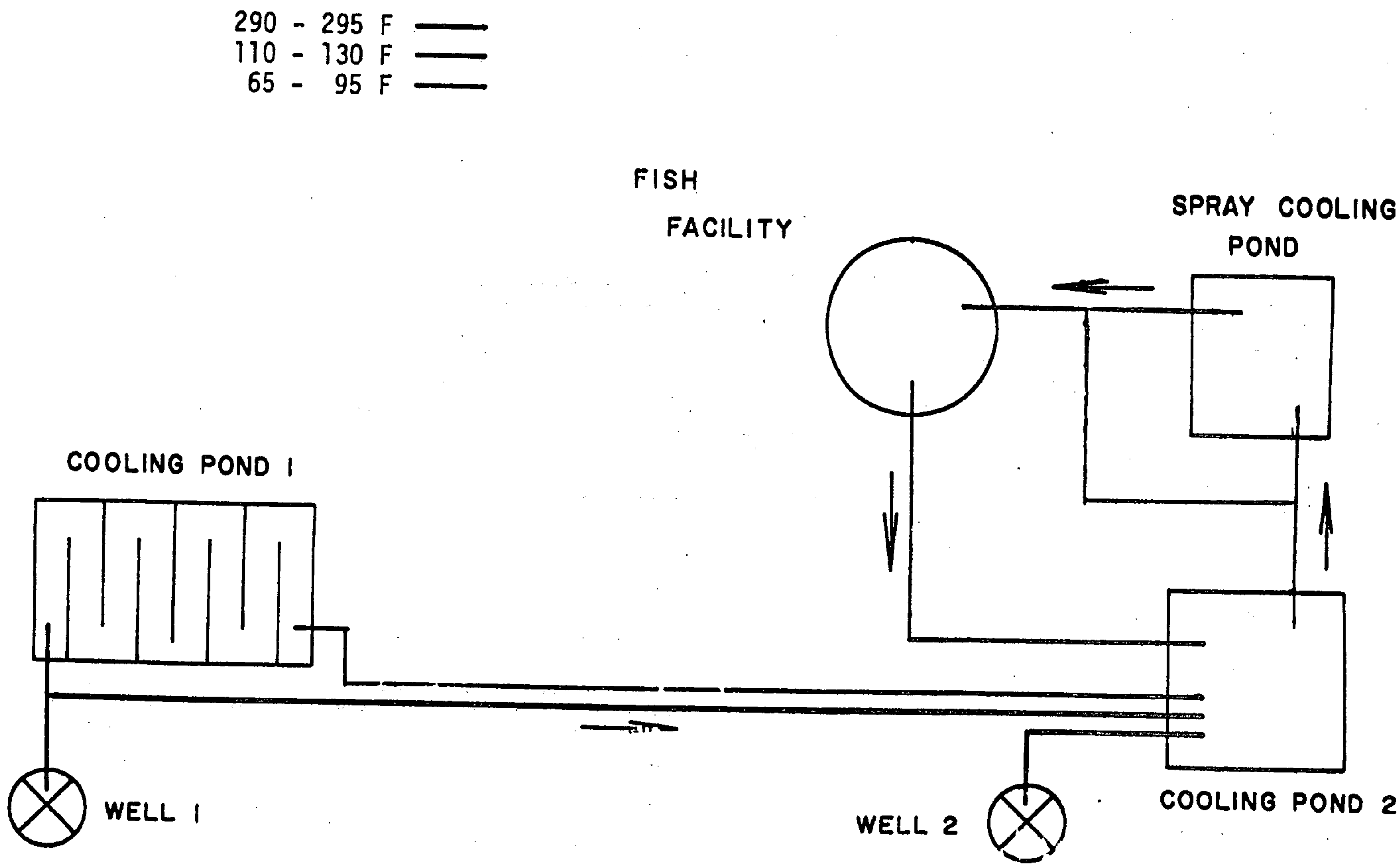


Table 1. Growth of Channel Catfish (*Ictalurus punctatus*) at the control site (Buhl, Idaho) and the ERDA Raft River Geothermal Site (RRGT). Replicate flow rates are: Low Flow - 2A and 2C; High Flow--2B and 2D. n = sample size.

DATE	SOURCE	TANK	TURN OVER TIME (min)	n	LENGTH (mm) $\bar{X} \pm$ S.E. (RANGE)	WEIGHT (gm) $\bar{X} \pm$ S.E. (RANGE)	CONDITION FACTOR (K)[1] X ± S.E. (RANGE)
8-22	Buhl[2]		5	199	100.96 ± 1.00 (70 - 135)	16.16 ± 0.48 (5.3 - 38.2)	1.49 ± 0.02 (1.07 - 3.46)
	RRGT	2A	90	50	101.24 ± 2.08 (76 - 135)	16.10 ± 0.99 (5.6 - 37.3)	1.47 ± 0.02 (1.20 - 2.48)
		2C	90	50	101.70 ± 1.84 (75 - 126)	16.67 ± 0.84 (7.2 - 28.5)	1.54 ± 0.04 (1.07 - 3.46)
		2B	10	50	100.02 ± 1.92 (70 - 131)	16.08 ± 0.91 (5.3 - 38.2)	1.53 ± 0.02 (1.28 - 1.83)
		2D	10	49	100.88 ± 2.19 (75 - 135)	15.79 ± 1.11 (6.4 - 36)	1.44 ± 0.02 (1.07 - 1.73)
9-03	RRGT	2A	90	16	102.13 ± 4.35 (79 - 139)	16.74 ± 2.00 (8.1 - 38)	1.50 ± 0.02 (1.12 - 1.77)
		2C	90	16	108.13 ± 2.87 (85 - 125)	17.59 ± 1.37 (8.3 - 27.0)	1.36 ± 0.05 (0.97 - 1.95)
		2B	10	16	107.31 ± 3.68 (81 - 138)	17.81 ± 1.53 (8.3 - 32.3)	1.42 ± 0.06 (1.02 - 1.96)
		2D	10	16	104.81 ± 3.15 (87 - 129)	16.2 ± 1.45 (9.3 - 32.2)	1.38 ± 0.07 (0.88 - 1.84)
9-10	Buhl		5	12	108.50 ± 3.74 (85 - 132)	20.93 ± 1.76 (11.7 - 32.5)	1.61 ± 0.04 (1.41 - 1.91)

1 Condition Factor K: $K = \text{weight}/\text{length}^3 \times 100{,}000$

2 All fish used thru this experiment originated from a commercial aquaculture operation in Buhl, Idaho.

Table 1 (Continued)

9-17	RRGT	2A	90	16	110.13 ± 3.53 (84 - 129)	18.38 ± 1.41 (9.7 - 29.0)	1.37 ± 0.06 (0.88 - 1.97)
		2C	90	16	109.25 ± 3.91 (81 - 143)	18.21 ± 1.48 (7.7 - 29.2)	1.37 ± 0.05 (0.99 - 1.65)
		2B	10	16	115.25 ± 2.97 (95 - 137)	21.85 ± 1.65 (13.0 - 36.1)	1.41 ± 0.05 (1.11 - 1.92)
		2D	10	16	111.50 ± 4.63 (90 - 158)	20.09 ± 2.27 (11.7 - 48)	1.42 ± 0.02 (0.82 - 1.64)
10-01	RRGT	2A	90	16	105.63 ± 3.72 (78 - 126)	18.14 ± 1.67 (7.1 - 30.3)	1.48 ± 0.03 (1.27 - 1.72)
		2C	90	16	106.56 ± 2.72 (79 - 123)	15.97 ± 1.15 (6.1 - 23.1)	1.28 ± 0.02 (1.16 - 1.43)
		2B	10	16	113.18 ± 2.92 (90 - 141)	21.81 ± 1.97 (11.6 - 41.9)	1.45 ± 0.04 (1.23 - 1.83)
		2D	10	16	115.25 ± 3.76 (97 - 143)	23.11 ± 2.38 (10.1 - 42.8)	1.44 ± 0.03 (1.04 - 1.58)
10-08	Buhl		5	12	111.08 ± 5.41 (86 - 156)	20.37 ± 3.58 (6.5 - 54.6)	1.35 ± 0.04 (1.02 - 1.57)
10-15	RRGT	2A	90	16	116.88 ± 5.01 (60 - 147)	23.14 ± 1.84 (5.7 - 43.2)	1.42 ± 0.09 (1.18 - 2.64)
		2C	90	16	104.81 ± 3.56 (84 - 135)	14.59 ± 1.57 (6.2 - 25.9)	1.20 ± 0.04 (0.87 - 1.42)
		2B	10	Fish in high flow tanks were inadvertantly killed on 10-11-76.			
		2D	10				
10-29	RRGT	2A	90	16	110.25 ± 4.90 (86 - 148)	20.46 ± 2.67 (7.2 - 42.7)	1.41 ± 0.03 (1.13 - 1.69)
		2C	90	16	106.37 ± 2.95 (87 - 124)	15.62 ± 1.33 (8.9 - 24.5)	1.26 ± 0.03 (1.07 - 1.53)
11-05	Buhl		5	12	124.83 ± 6.03 (105 - 185)	30.63 ± 5.38 (14.4 - 86.3)	1.46 ± 0.04 (1.24 - 1.61)

Table 1 (Continued)

11-12	RRGT	2A	90	16	115.31 ± 4.16 (90 - 138)	19.83 ± 2.34 (7.0 - 33.2)	1.19 ± 0.02 (0.93 - 1.32)
		2C	90	16	106.63 ± 3.12 (86 - 123)	14.84 ± 1.50 (5.7 - 23.6)	1.15 ± 0.03 (0.87 - 1.30)
11-29	RRGT	2A	90	14	115.00 ± 4.75 (85 - 144)	19.98 ± 2.97 (5.9 - 43.0)	1.17 ± 0.05 (0.78 - 1.44)
		2C	90	15	110.53 ± 3.47 (89 - 129)	16.57 ± 1.84 (6.3 - 29.2)	1.15 ± 0.06 (0.89 - 1.36
12-03	Buhl		5	12	128.75 ± 4.98 (105 - 147)	31.41 ± 4.25 (10.8 - 52.3)	1.36 ± 0.06 (0.93 - 1.71)

Table 1.1. Pooled Data: Growth of Channel Catfish (*Ictalurus punctatus*) at the control site (Buhl, Idaho) and the ERDA Raft River Geothermal site (RRGT) over the experimental period. The analysis of covariance ($\alpha = .05$) was used to determine if significant differences existed between replicate flow rates in regards to growth. No significant differences were found between replicates. They have thus been pooled below. Low flow -- 2A + 2C = 2AC, high flow -- 2B + 2D = 2BD. n = sample size.

DATE	SOURCE	TANK	TURN OVER TIME (min)	n	LENGTH (mm) X + S.E. (RANGE)	WEIGHT (gm) X + S.E. (RANGE)	CONDITION FACTOR (K)[1] X + S.E. (RANGE)
8-22	Buhl	Control	5	199	100.86 ± 1.00 (70 - 135)	16.16 ± 0.48 (5.3 - 37.3)	1.49 ± 0.02 (1.07 - 3.46)
	RRGT	2AC	90	100	101.47 ± 1.38 (75 - 135)	16.39 ± 0.65 (5.7 - 37.5)	1.51 ± 0.03 (1.06 - 3.46)
		2BD	10	99	100.49 ± 1.45 (70 - 135)	15.94 ± 0.71 (5.3 - 38.2)	1.49 ± 0.02 (1.07 - 1.83)
9-3	RRGT	2AC	90	32	105.13 ± 2.62 (79 - 139)	17.17 ± 1.20 (8.1 - 38.0)	1.43 ±.04 (0.97 - 1.95)
		2BD	10	32	106.06 ± 2.40 (81 - 138)	17.00 ± 1.05 (8.3 - 32.3)	1.40 ± .04 (0.88 - 1.96)
9-10	Buhl	Control	5	12	108.50 ± 3.74 (85 - 132)	20.93 ± 1.76 (11.7 - 32.5)	1.61 ± 0.04 (1.41 - 1.91)
9-17	RRGT	2AC	90	32	109.69 ± 2.59 (81 - 143)	18.30 ± 1.01 (7.7 - 29.2)	1.37 ± .04 (0.88 - 1.97)
		2BD	10	32	113.38 ± 2.73 (90 - 158)	20.98 ± 1.39 (11.7 - 48.0)	1.41 ± .04 (0.82 - 1.92)
10-1	RRGT	2AC	90	32	106.09 ± 2.27 (78 - 126)	17.06 ± 1.02 (6.1 - 30.3)	1.38 ± .03 (1.16 - 1.72)
		2BD	10	32	114.22 ± 2.35 (90 - 143)	22.46 ± 1.52 (10.1 - 42.8)	1.44 ± .02 (1.04 - 1.83)
10-8	Buhl	Control	5	12	111.08 ± 5.41 (86 - 156)	20.38 ± 3.58 (6.5 - 54.6)	1.35 ± .04 (1.02 - 1.57)

[1] Condition Factor (K): $K = \text{weight}/\text{length}^3 \times 100000$

Table 1.1 (Continued)

10-15	RRGT	2AC	90	32	110.84 ± 3.21 (60 - 147)	18.86 ± 1.59 (5.7 - 43.2)	1.31 ± .05 (0.87 - 2.64)
		2BD	Fish in high flow tanks inadvertently killed during week of 10-11-76.				
11-5	Buhl	Control	5	12	124.83 ± 6.03 (105 - 185)	30.63 ± 5.38 (14.4 - 86.3)	1.46 ± .04 (1.24 - 1.61)
12-3	Buhl	Control	5	12	128.75 ± 4.98 (105 - 147)	31.41 ± 4.25 (10.8 - 52.3)	1.36 ± .06 (0.93 - 1.71)

Fig. 1. Channel Catfish weight gain and condition factor fluctuation over the experimental period.

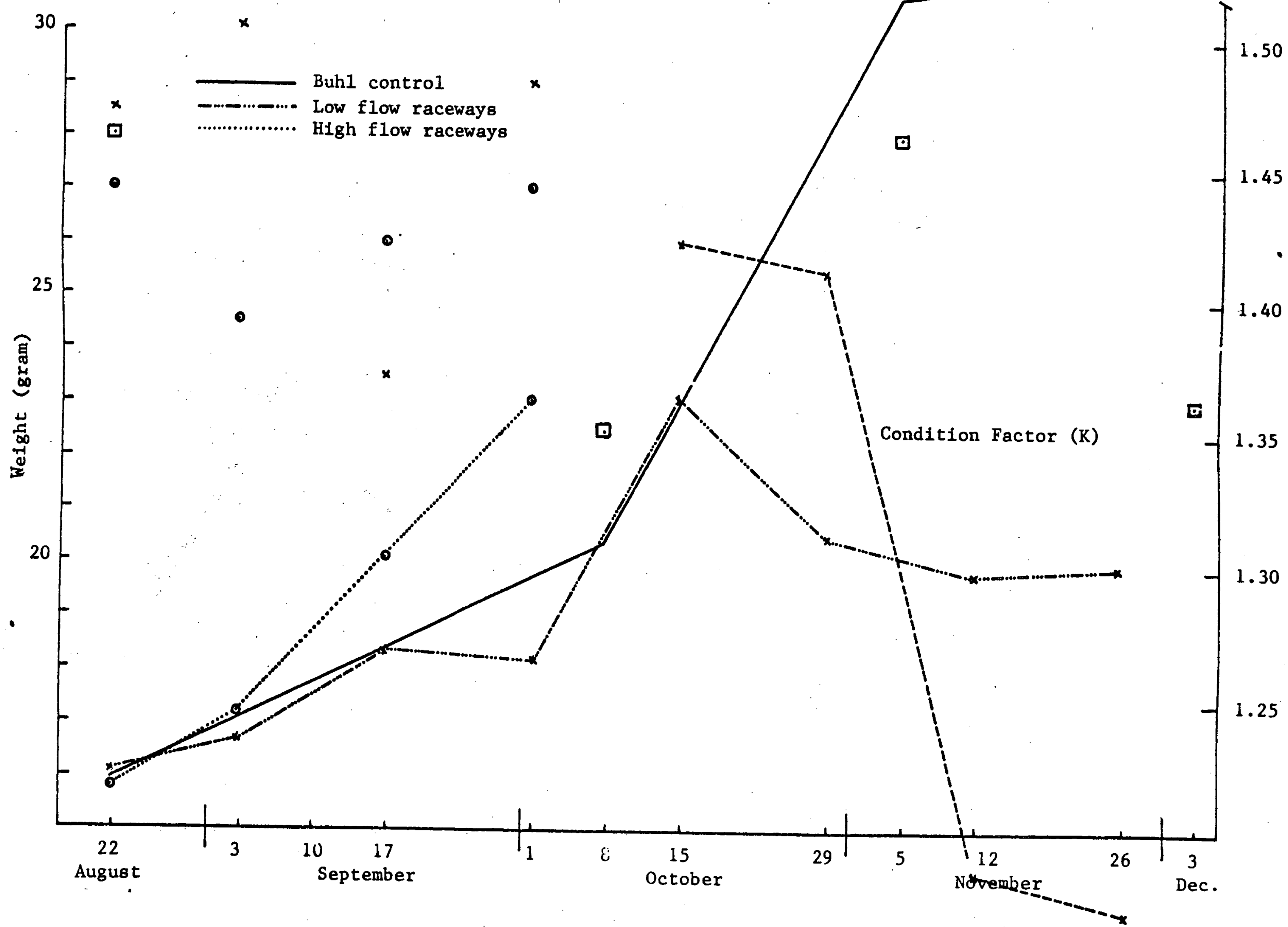


Fig. 1.1. Linear regressions of weight v. time for Channel Catfish at the ERDA RRGT. Replicate flow rates have been pooled: Low flow - 2AC, high flow - 2BD. Controls are from Buhl, Idaho.

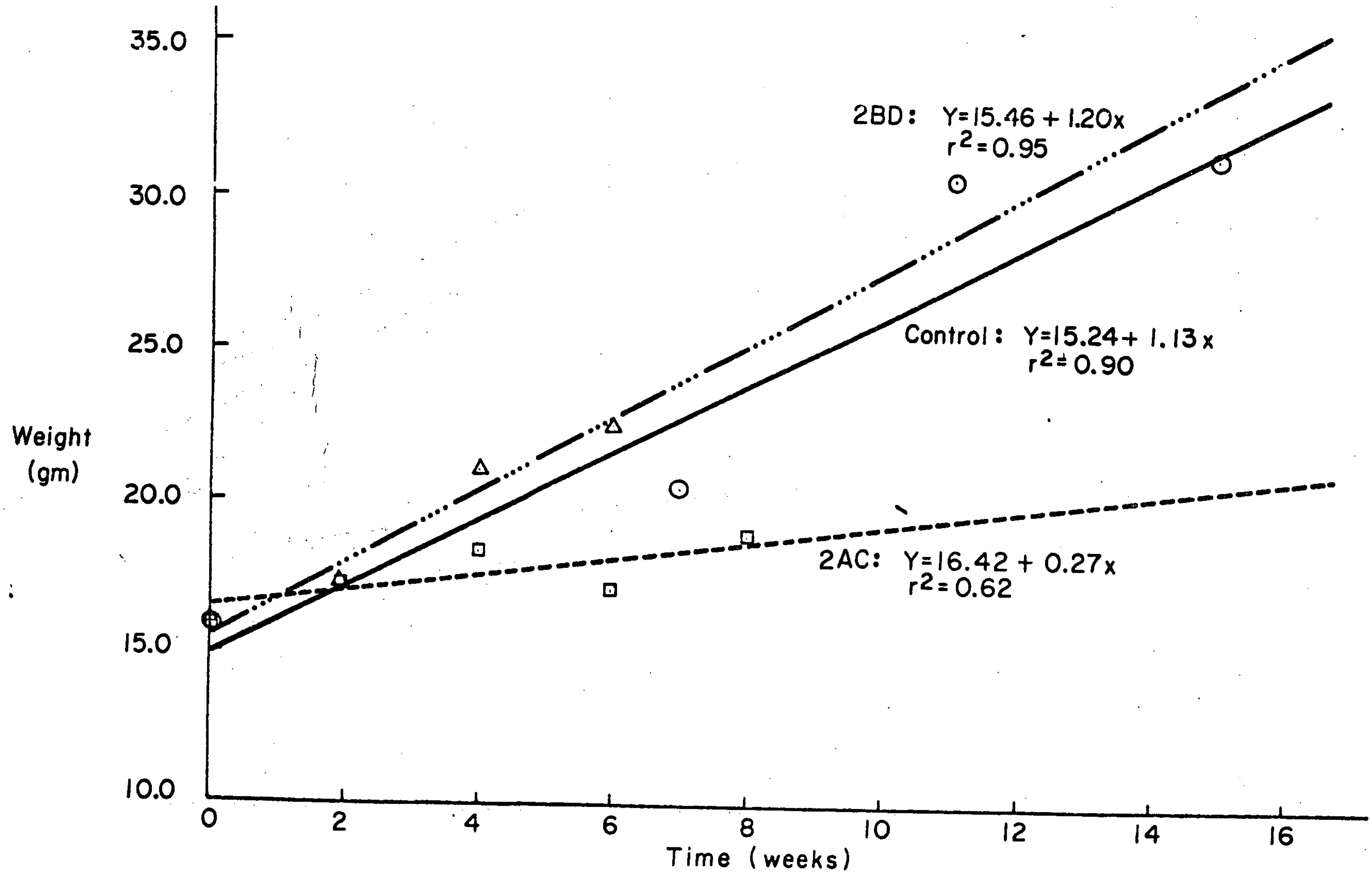


Fig. 1.2. Linear regressions of standard length v. time for Channel Catfish at the ERDA RRGT. Replicate flow rates have been pooled: Low flow - 2AC, high flow - 2 BD. Controls are from Buhl, Idaho.

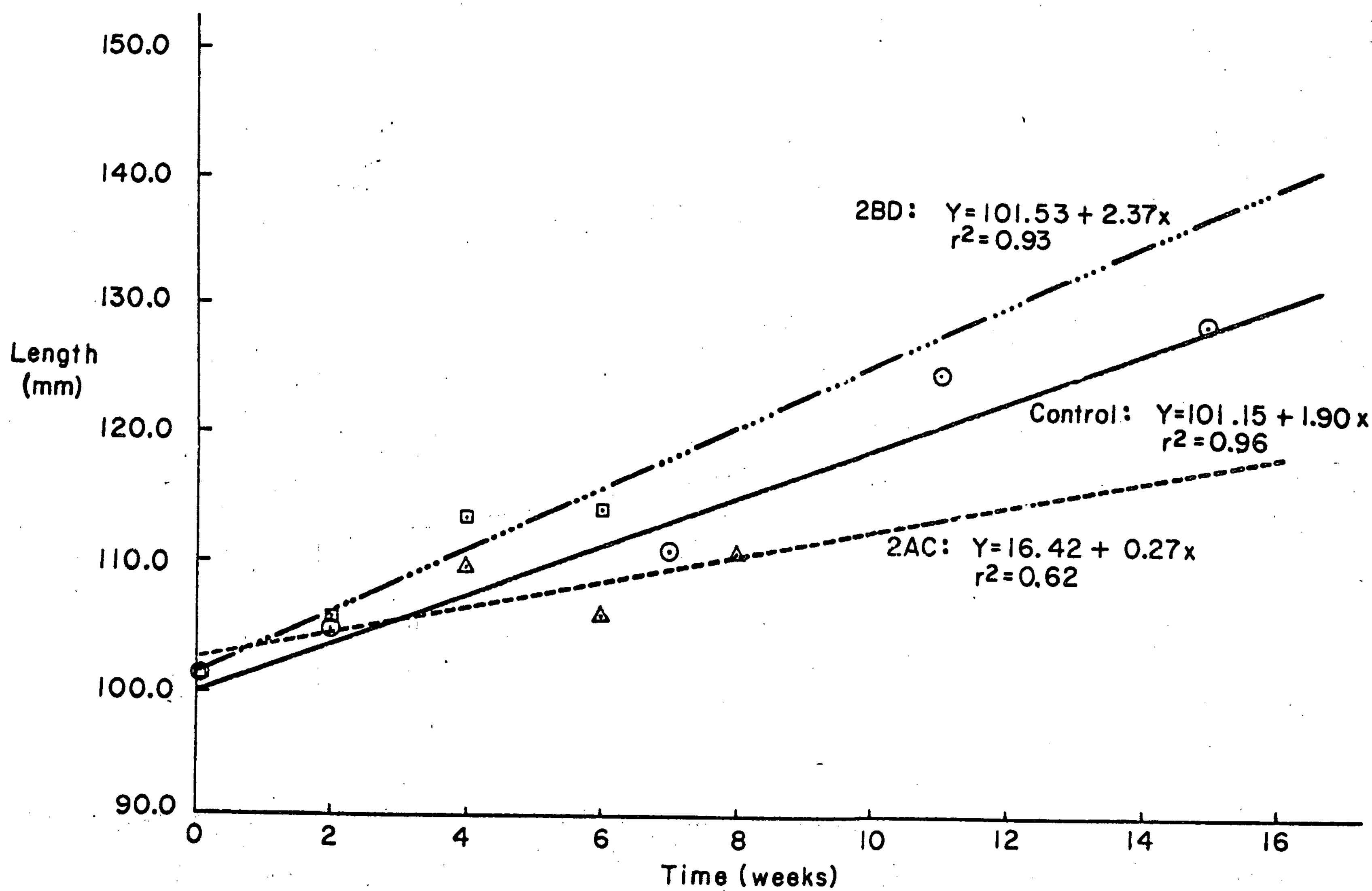


Table 2. Growth of *Tilapia zillii* in control water (Buhl, Idaho) and geothermal water at the ERDA Raft River geothermal site (RRGT). Replicate flow rates are: Low Flow - 3A and 3C; High Flow - 3B and 3D. n= sample size

DATE	WATER SOURCE	TANK	TURN OVER TIME (min)	n	LENGTH (mm) $\bar{X}$ + S.E. (RANGE)	DEPTH (mm) $\bar{X}$ + S.E. (RANGE)	WEIGHT (gm) $\bar{X}$ ± S.E. (RANGE)	CONDITION[1] FACTOR (K) $\bar{X}$ ± S.E. (RANGE)	CONDITION[2] FACTOR (Z) $\bar{X}$ ± S.E. (RANGE)
8-20	Buhl[3]			199	53.34 ± 0.53 (38-104)	19.21 ± 0.20 (11-38)	6.71 ± 0.24 (2.4-41.4)	4.23 ± 0.04 (1.80-6.61)	3.61 ± 0.02 (3.18-4.51)
	RRGT	3A	90	50	51.64 ± 0.98 (38-63)	19.06 ± 0.41 (14-24)	6.13 ± 0.30 (2.8-9.8)	4.32 ± 0.07 (3.16-6.09)	3.69 ± 0.04 (3.25-4.51)
		3C	90	50	54.10 ± 0.86 (39-70)	19.10 ± 0.31 (14-25)	6.83 ± 0.38 (2.4-18.5)	4.14 ± 0.04 (3.32-5.39)	3.53 ± 0.02 (3.33-3.43)
		3B	10	49	56.43 ± 1.24 (45-104)	19.92 ± 0.46 (16-38)	7.79 ± 0.76 (3-41.4)	4.07 ± 0.07 (1.80-5.58)	3.52 ± 0.02 (3.64-3.73)
		3D	10	50	51.26 ± 1.00 (37-65)	18.76 ± 0.37 (11-23)	6.10 ± 0.32 (2.5-11.3)	4.38 ± 0.08 (3.13-6.61)	3.67 ± 0.04 (3.18-4.05)
9-03	RRGT	3A	90	15	58.07 ± 1.45 (66-47)	23.20 ± 0.75 (18-27)	7.91 ± 0.65 (4.1-13.5)	4.00 ± 0.20 (2.44-6.15)	4.00 ± 0.10 (3.33-4.64)
		3C	90	16	62.75 ± 1.52 (55-81)	24.59 ± 0.76 (21-32)	9.73 ± 0.83 (6.1-19.5)	3.84 ± 0.12 (3.27-4.95)	3.92 ± 0.07 (3.55-4.50)
		3B	10	16	66.38 ± 0.61 (61-70)	25.75 ± 0.30 (23-28)	10.64 ± 0.36 (7.2-13.0)	3.63 ± 0.08 (3.17-4.15)	3.88 ± 0.04 (3.77-3.85)
		3D	10	16	59.75 ± 1.70 (46-73)	21.75 ± 0.86 (16-27)	7.44 ± 0.69 (3.1-13.0)	3.37 ± 0.16 (2.88-5.64)	3.63 ± 0.08 (3.54-4.66)
9-10	Buhl			12					

1 Condition Factor K: K = weight/length^3 x 100000

2 Condition Factor Z: Z = Body depth/length x 10

3 All fish used in this experiment originated from a commercial aquaculture operation in Buhl, Idaho.

Table 2. (Continued)

9-17	RRGT	3A	90	15	63.00 ± 2.18 (52-77)	23.73 ± 1.18 (18-28)	10.49 ± 0.89 (6.6-16.2)	4.12 ± 0.13 (3.19-4.90)	3.76 ± 0.12 (3.60-4.80)
		3C	90	16	67.94 ± 1.47 (56-80)	26.13 ± 0.61 (22-33)	11.73 ± 0.71 (7.0-18.7)	3.69 ± 0.04 (3.40-3.99)	3.85 ± 0.03 (3.66-4.13)
		3B	10	16	71.81 ± 1.68 (61-82)	27.88 ± 0.97 (23-39)	14.02 ± 1.00 (8.2-22.0)	3.68 ± 0.04 (3.44-4.03)	3.87 ± 0.06 (3.66-4.76)
		3D	10	16	66.44 ± 1.83 (54-79)	24.81 ± 0.75 (21-29)	11.19 ± 0.89 (6.0-17.8)	3.69 ± 0.04 (3.39-3.93)	3.73 ± 0.03 (3.56-3.89)
10-01	RRGT	3A	90	16	63.63 ± 2.19 (52-82)	25.13 ± 0.89 (18-29)	10.12 ± 1.14 (2.3-18.7)	2.87 ± 0.12 (1.55-3.39)	3.66 ± 0.04 (3.39-4.03)
		3C	90	16	70.00 ± 2.11 (52-88)	26.19 ± 0.85 (19-33)	11.07 ± 1.20 (2.2-22.0)	2.99 ± 0.12 (1.56-3.59)	3.74 ± 0.03 (3.47-3.92)
		3B	10	16	75.75 ± 0.28 (63-114)	27.69 ± 0.97 (23-40)	14.43 ± 2.38 (6.7-48.2)	3.05 ± 0.06 (2.57-3.39)	3.66 ± 0.03 (3.51-3.82)
		3D	10	16	67.63 ± 2.39	23.94 ± 0.95	10.68 ± 1.32	3.23 ± 0.15	3.54 ± 0.04
10-08	Buhl			12	67.25 ± 0.99 (61-74)	28.42 ± 0.48 (26-31)	10.29 ± 0.60 (6.4-15.1)	3.35 ± 0.10 (2.82-3.83)	4.23 ± 0.03 (4.03-4.39)
10-15	RRGT	3A	90	16	74.25 ± 2.12 (58-85)	28.63 ± 1.22 (21-38)	15.69 ± 1.51 (5.6-27)	3.63 ± 0.13 (2.87-4.90)	3.84 ± 0.07 (3.44-4.63)
		3C	90	16	73.44 ± 0.26 (50-94)	27.44 ± 1.12 (18-36)	15.12 ± 1.57 (4.4-30.8)	3.61 ± 0.07 (3.81-4.11)	3.73 ± 0.04 (3.57-3.97)
		3B	10	16	77.81 ± 0.31 (64-118)	29.13 ± 1.16 (23-43)	16.26 ± 0.26 (9.5-51)	3.26 ± 0.17 (0.88-3.86)	3.74 ± 0.02 (3.59-3.92)
		3D	10	16	69.75 ± 0.03 (50-83)	24.69 ± 1.19 (19-31)	12.29 ± 1.27 (5.4-21.0)	3.50 ± 0.16 (2.38-5.12)	3.57 ± 0.14 (1.73-4.60)
10-29	RRGT	3A	90	16	71.00 ± 3.19 (48-89)	28.31 ± 1.52 (17-40)	17.24 ± 2.24 (6.5-36.6)	4.23 ± 0.13 (3.77-5.88)	3.97 ± 0.07 (3.54-4.49)
		3C	90	16	74.75 ± 3.09 (49-95)	28.81 ± 1.24 (18-40)	18.06 ± 2.04 (5.1-36.1)	4.13 ± 0.17 (1.77-4.77)	3.87 ± 0.09 (2.98-4.21)
		3B	10	16	70.13 ± 2.54 (55-92)	27.31 ± 1.05 (21-37)	14.99 ± 1.52 (7.3-30.9)	4.17 ± 0.07 (3.78-4.77)	3.89 ± 0.03 (3.79-4.05)
		3D	10	16	70.69 ± 2.59 (58-85)	27.31 ± 1.12 (21-34)	15.43 ± 1.52 (7.4-24.4)	4.19 ± 0.33 (3.79-5.74)	3.86 ± 0.05 (3.50-4.31)

Table 2. (Continued)

11-05	Buhl			12	61.67 ± 1.29 (55-68)	25.67 ± 0.51 (23-29)	8.81 ± 0.45 (6.3-11.2)	3.75 ± 0.10 (2.95-4.44)	4.17 ± 0.05 (3.96-4.55)
11-12	RRGT	3A	90	16	71.19 ± 2.87 (50-92)	26.75 ± 1.36 (17-36)	13.45 ± 1.94 (3.5-29.5)	3.33 ± 0.11 (2.73-4.19)	3.74 ± 0.05 (3.40-4.09)
		3C	90	16	77.38 ± 1.59 (64-85)	29.31 ± 0.77 (23-33)	15.29 ± 1.06 (7.7-21.2)	3.21 ± 0.24 (2.94-3.76)	3.78 ± 0.04 (3.53-4.07)
		3B	10	12	74.33 ± 2.88 (59-91)	28.08 ± 1.38 (22-37)	14.37 ± 2.03 (6.1-28.1)	3.23 ± 0.09 (2.96-3.53)	3.76 ± 0.04 (3.53-3.98)
		3D	10	16	71.69 ± 2.96 (55-93)	26.31 ± 1.09 (20-34)	11.74 ± 1.61 (3.9-25.1)	2.93 ± 0.12 (2.18-4.39)	3.67 ± 0.04 (3.39-4.18)
11-26	RRGT	3A	90	13	65.62 ± 3.35 (49-91)	24.92 ± 1.43 (18-36)	12.73 ± 2.21 (4.1-32.2)	4.07 ± 0.12 (3.49-4.97)	3.79 ± 0.03 (3.57-3.96)
		3C	90	12	74.25 ± 3.54 (49-86)	29.17 ± 1.43 (18-35)	18.29 ± 2.02 (5.7-28.4)	4.32 ± 0.20 (3.55-6.03)	3.93 ± 0.08 (3.52-4.63)
		3B	10	7	74.23 ± 3.73 (59-88)	28.00 ± 1.75 (22-33)	16.34 ± 2.22 (8.5-25.4)	3.83 ± 0.07 (3.64-4.14)	3.75 ± 0.09 (3.58-4.08)
		3D	10	10	70.00 ± 3.20 (55-92)	26.70 ± 1.29 (20-35)	13.53 ± 1.90 (6.2-28.3)	3.76 ± 0.42 (3.51-4.07)	3.81 ± 0.04 (3.64-4.03)
12-03	Buhl			12	64.83 ± 1.52 (59-73)	25.42 ± 0.69 (22-30)	9.93 ± 0.78 (6.7-14.4)	3.56 ± 0.05 (3.10-3.70)	3.92 ± 0.04 (3.67-4.11)

Table 2.1. Growth of *Tilapia zillii* in control water (Buhl, Idaho) and geothermal water at the ERDA Raft River Geothermal Site (RRGT) over the experimental period. The Analysis of Covariance (= 0.05) was used to determine if significant differences existed between replicate flow rates with regards to growth. If significant differences were not evidenced, replicates were pooled. Only the two (2) low flow replicate tanks could be pooled. Thus, low flow -- 3A + 3C = 3AC, high flow -- 3B, 3D. n = sample size.

DATE	WATER SOURCE	TANK	TURN OVER TIME (min)	n	LENGTH (mm) X + S.E. (RANGE)	DEPTH (mm) X + S.E. (RANGE)	WEIGHT (gm) X + S.E. (RANGE)	CONDITION[1] FACTOR (K) X + S.E. (RANGE)	CONDITION[2] FACTOR (Z) X + S.E. (RANGE)
8-20	Buhl		12	199	53.54 ± 0.53 (38 - 104)	19.21 ± 0.20 (11 - 38)	6.71 ± 0.24 (2.4 - 41.4)	4.43 ± 0.04 (1.80 - 6.61)	3.61 ± 0.02 (3.18 - 4.51)
	RRGT	3AC	90	100	52.87 ± 0.66 (38 - 70)	19.08 ± 0.25 (14 - 25)	6.48 ± 0.38 (2.4 - 18.5)	4.23 ± 0.04 (3.16 - 6.09)	3.61 ± 0.02 (3.25 - 4.51)
		3B	10	49	56.43 ± 1.24 (45 - 104)	19.92 ± 0.46 (16 - 38)	7.79 ± 0.76 (3.0 - 41.4)	4.07 ± 0.07 (1.80 - 5.58)	3.52 ± 0.02 (3.64 - 3.73)
		3D	10	50	51.26 ± 1.00 (37 - 65)	18.76 ± 0.37 (11 - 23)	6.10 ± 0.32 (2.5 - 11.3)	4.38 ± 0.08 (3.13 - 6.61)	3.67 ± 0.04 (3.18 - 4.05)
9-03	RRGT	3AC	90	31	60.48 ± 1.12 (55 - 81)	23.92 ± 0.54 (18 - 32)	8.85 ± 0.55 (4.1 - 19.5)	3.92 ± 0.13 (2.44 - 4.95)	3.96 ± 0.05 (3.33 - 4.66)
		3B	10	16	66.38 ± 0.61 (61 - 70)	25.75 ± 0.30 (23 - 28)	10.64 ± 0.36 (7.2 - 13.0)	3.63 ± 0.08 (3.17 - 4.15)	3.88 ± 0.04 (3.77 - 3.85)
		3D	10	16	59.75 ± 1.71 (46 - 73)	21.75 ± 0.86 (16 - 27)	7.74 ± 0.69 (3.1 - 13.0)	3.37 ± 0.16 (2.88 - 5.64)	3.63 ± 0.08 (3.54 - 4.66)
9-10	Buhl		12	12	59.07 ± 1.55 (50 - 66)	20.5 ± 0.38 (18 - 22)	8.67 ± 0.67 (4.9 - 11.8)	4.11 ± 0.03 (3.85 - 4.21)	3.48 ± 0.03 (3.31 - 3.68)

1 Condition Factor (K): $K = \text{weight}/\text{length}^3 \times 100000$

2 Condition Factor (Z): $Z = \text{body depth}/\text{length} \times 10$

Table 2.1 (Continued)

9-17	RRGT	3AC	90	31	65.55 ± 1.35	24.97 ± 0.68	11.13 ± 0.57	3.89 ± 0.08	3.80 ± 0.06
					(52 - 80)	(18 - 33)	(6.6 - 18.6)	(3.19 - 4.90)	(3.60 - 4.80)
		3B	10	16	71.81 ± 1.68	27.88 ± 0.97	14.02 ± 1.00	3.68 ± 0.04	3.87 ± 0.06
					(61 - 82)	(23 - 39)	(8.2 - 22.0)	(3.44 - 4.03)	(3.66 - 4.76)
		3D	10	16	66.44 ± 1.83	24.81 ± 0.75	11.19 ± 0.89	3.69 ± 0.04	3.73 ± 0.03
					(54 - 79)	(21 - 29)	(6.0 - 17.8)	(3.39 - 3.93)	(3.56 - 3.89)
10-01	RRGT	3AC	90	32	69.31 ± 1.50	25.66 ± 0.61	10.59 ± 0.83	2.93 ± 0.09	3.70 ± 0.03
					(52 - 88)	(18 - 33)	(2.2 - 22.0)	(1.55 - 3.59)	(3.39 - 4.03)
		3B	10	16	75.75 ± 0.28	27.69 ± 0.97	14.43 ± 2.38	3.05 ± 0.06	3.66 ± 0.03
					(63 - 11)	(23 - 40)	(6.7 - 48.2)	(2.57 - 3.39)	(3.51 - 3.82)
		3D	10	16	67.63 ± 2.39	23.94 ± 0.95	10.68 ± 1.32	3.23 ± 0.15	3.54 ± 0.04
					(56 - 90)	(19 - 29)	(4.1 - 24.2)	(1.90 - 3.90)	(3.38 - 3.77)
10-08	Buhl		12	12	67.25 ± 0.99	28.42 ± 0.48	10.29 ± 0.60	3.35 ± 0.10	4.23 ± 0.03
					(61 - 74)	(26 - 31)	(6.4 - 15.1)	(2.82 - 3.83)	(4.03 - 4.39)
10-15	RRGT	3AC	90	32	73.84 ± 1.66	28.03 ± 0.82	15.41 ± 1.07	3.62 ± 0.01	3.78 ± 0.04
					(50 - 94)	(18- 38)	(4.4 - 30.8)	(2.87 - 4.90)	(3.44 - 4.63)
		3B	10	16	77.81 ± 0.31	29.13 ± 1.16	16.26 ± 0.26	3.26 ± 0.17	3.74 ± 0.02
					(64 - 118)	(23 - 43)	(9.5 - 51.0)	(0.88 - 3.86)	(3.59 - 3.92)
		3D	10	16	69.75 ± 0.03	24.69 ± 1.19	12.29 ± 1.27	3.50 ± 0.16	3.57 ± 0.14
					(50 - 84)	(19 - 31)	(5.4 - 21.0)	(2.38 - 5.12)	(1.73 - 4.60)
11-05	Buhl		12	12	61.67 ± 1.29	25.67 ± 0.51	8.81 ± 0.45	3.75 ± 0.10	4.17 ± 0.05
					(55 - 68)	(23 - 29)	(6.3 - 11.2)	(2.95 - 4.44)	(3.96 - 4.55)
12-03	Buhl		12	12	64.83 ± 1.52	25.42 ± 0.69	9.93 ± 0.78	3.56 ± 0.05	3.92 ± 0.04
					(59 - 73)	(22 - 30)	(6.7 - 14.4)	(3.10 - 3.70)	(3.67 - 4.11)

Fig. 2. Tilapia weight gain over the experimental period.

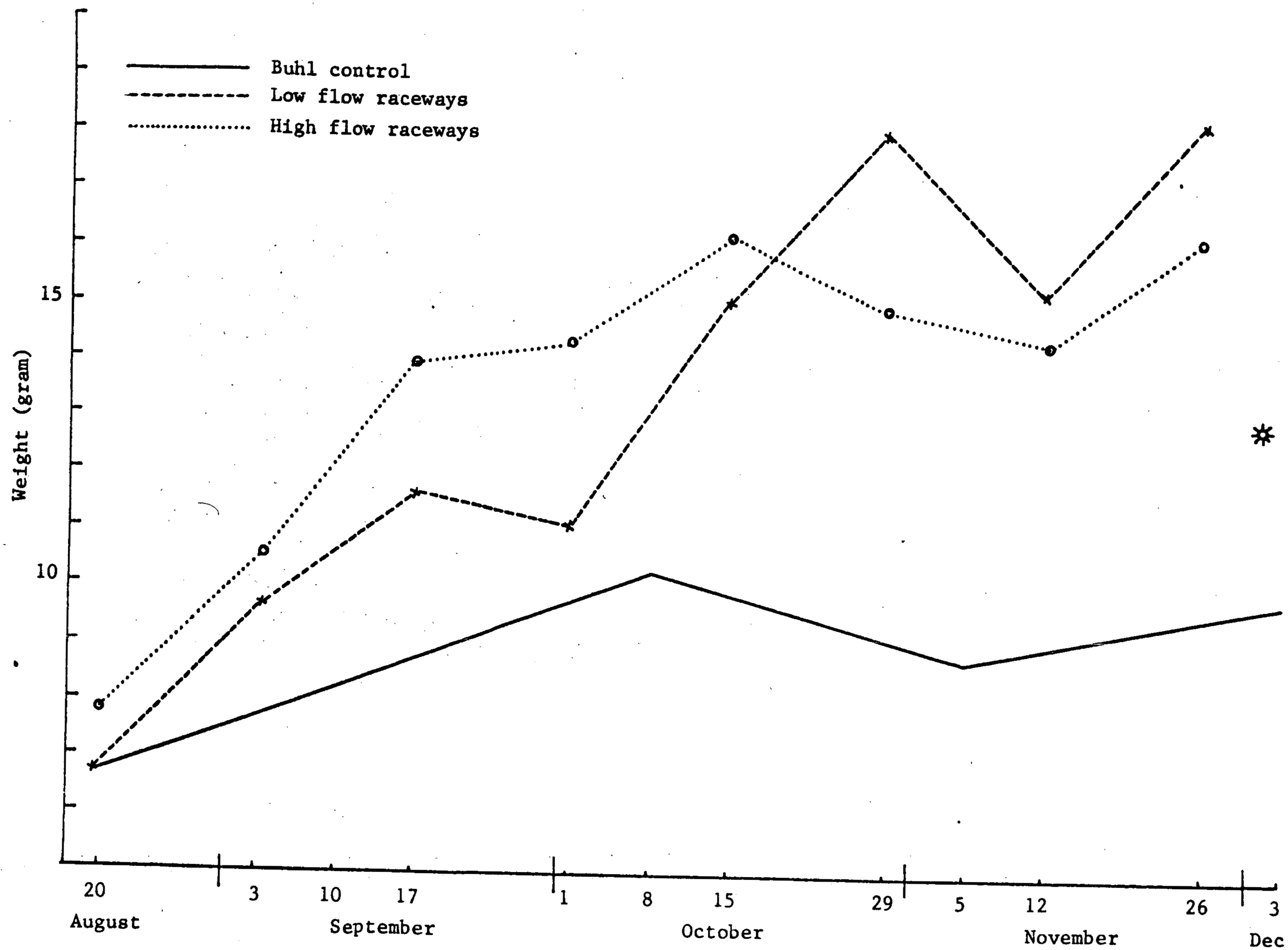


Fig. 2.1. Linear regressions of weight v. time for Tilapia zillii at the ERDA RRGT. Data from low flow (3AC) has been pooled. High flow replicates (3B and 3D) could not be pooled. Controls are from Buhl, Idaho.

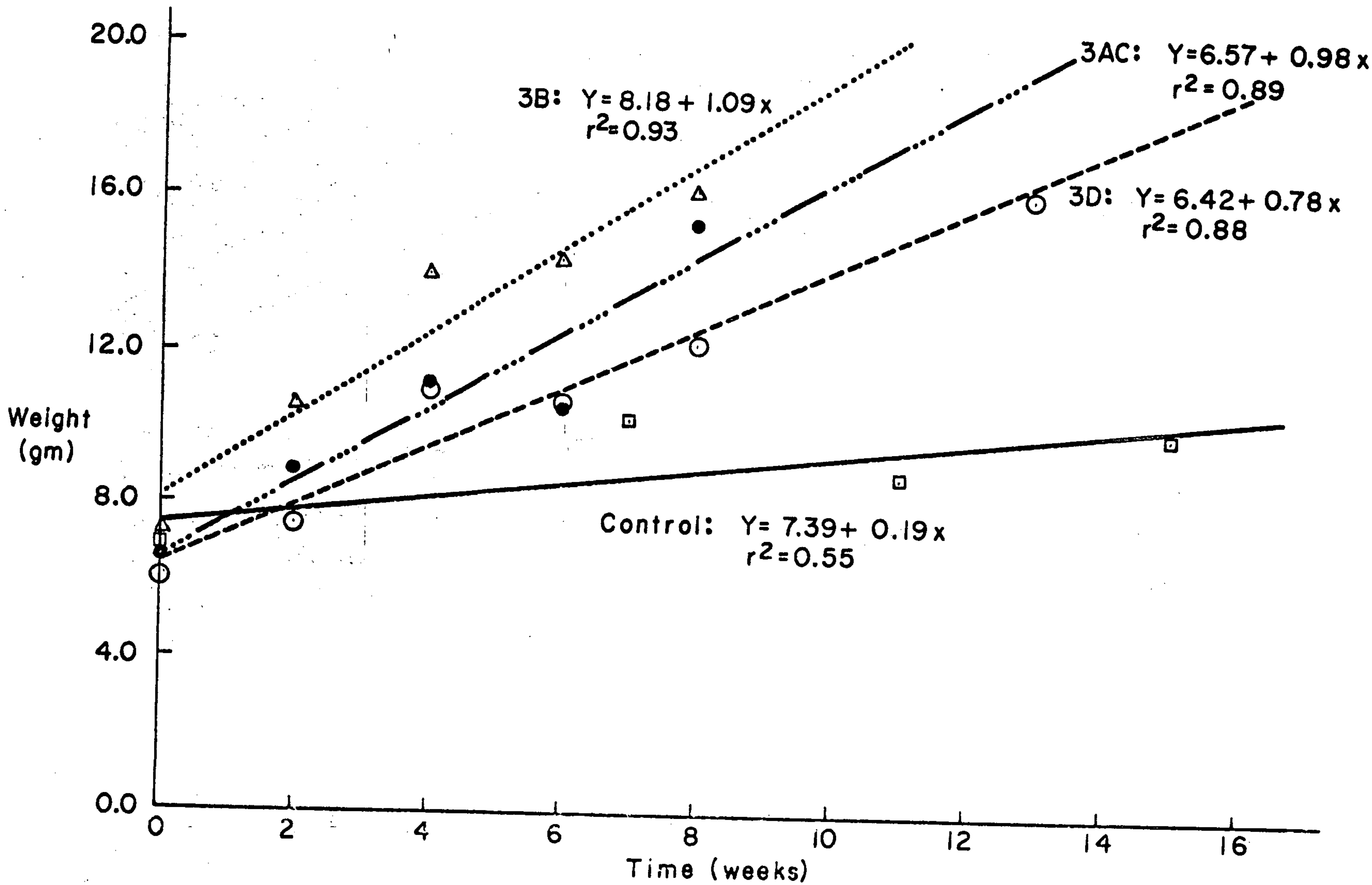


Fig. 2.2. Linear regressions of standard length v. time for *Tilapia zillii* at the ERDA RRGT. Data has been pooled as per Fig. 2.1. Low flow - 3AC, high flow - 3B, 3D. Controls are from Buhl, Idaho.

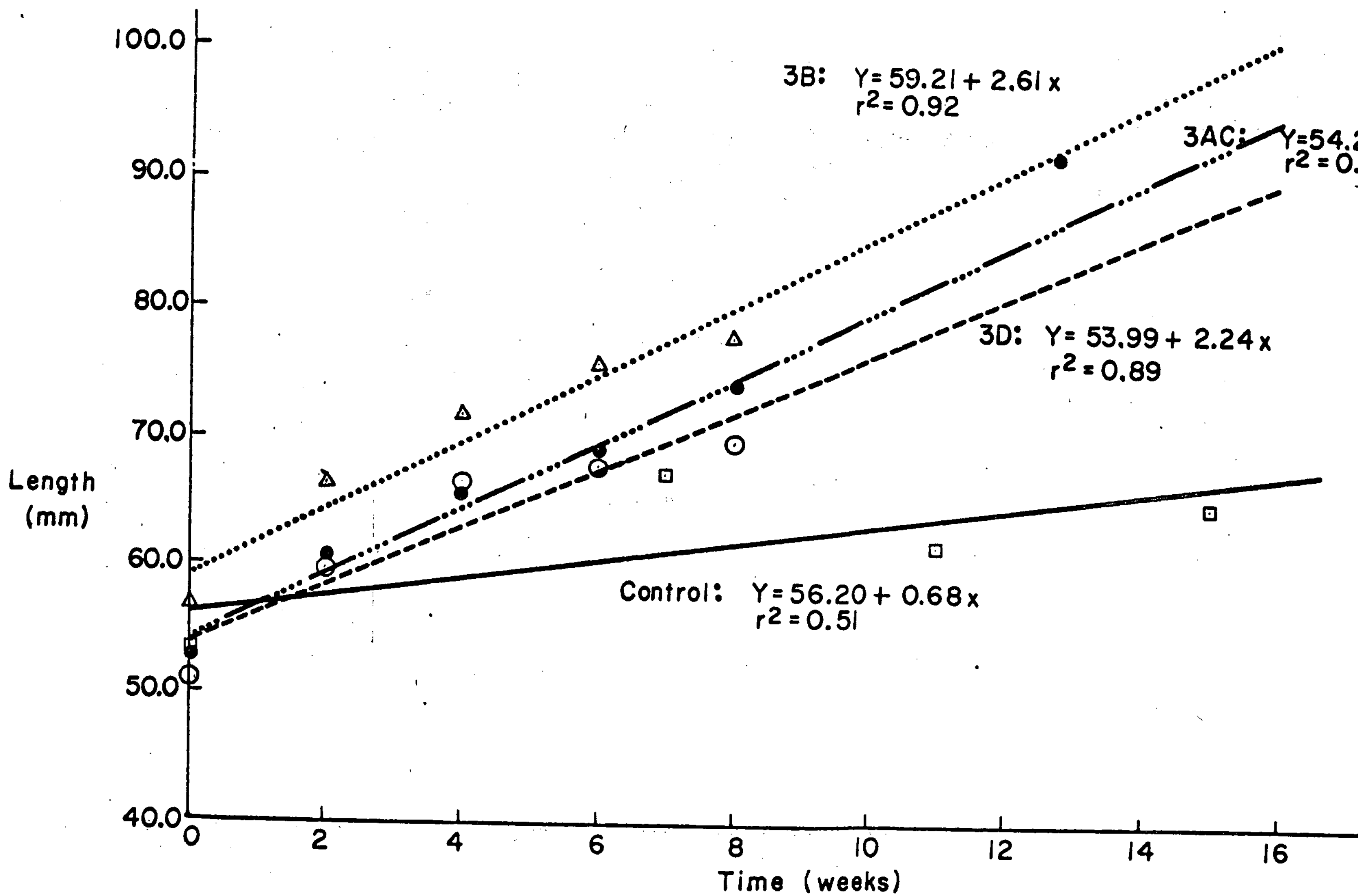


Table 3. Freshwater Prawn (*Macrobrachium rosenbergii*) growth at four stocking densities in water at the ERDA Raft River Geothermal Site (RRGT).

DATE	DAY	TANK	FLOW RATE (gpm)	STOCKING DENSITY (#/sq.ft.)	n	LENGTH (mm) Mean + S.E. (RANGE)	WEIGHT (gm) MEAN[1]
9-30	0	Initial Sample			145	21 ± 0.39 (10 - 40)	0.24
10-10	10	1	0.04	1.5	12	22 ± 1.08 (17 - 29)	0.22
		2	0.31	3.0	24	25 ± 0.94 (18 - 34)	0.43
		3	0.11	6.0	24	23 ± 0.88 (16 - 30)	0.35
		4	0.52	12.0	24	23 ± 0.80 (18 - 33)	0.43
10-23	23	1			9	26 ± 1.44 (19 - 33)	0.42
		2			9	27 ± 1.67 (21 - 34)	0.68
		3			10	31 ± 1.44 (25 - 35)	0.89
		4			10	28 ± 1.21 (24 - 35)	0.69
11-9	40	1			9	31 ± 1.18 (27 - 37)	0.89
		2			10	37 ± 1.85 (29 - 46)	1.39
		3			10	34 ± 1.61 (25 - 40)	1.10
		4[2]					

[1]Mean = $\frac{\text{total weight}}{n}$

[2]All prawns dead

Table 3. (Continued)

11-19	50	1	10	34 ± 1.09 (30 - 40)	0.58
		2	10	41 ± 1.76 (30 - 48)	1.40
		3	10	40 ± 1.36 (34 - 46)	1.25
11-29	60	1[2]			
		2	3[3]	42 ± 2.03 (38 - 45)	1.40
		3	20	40 ± 1.25 (30 - 54)	1.20

[3]Only 3 survivors

Fig. 3. Prawn growth in length at four flow rates and stocking densities at the Raft River Geothermal Site.

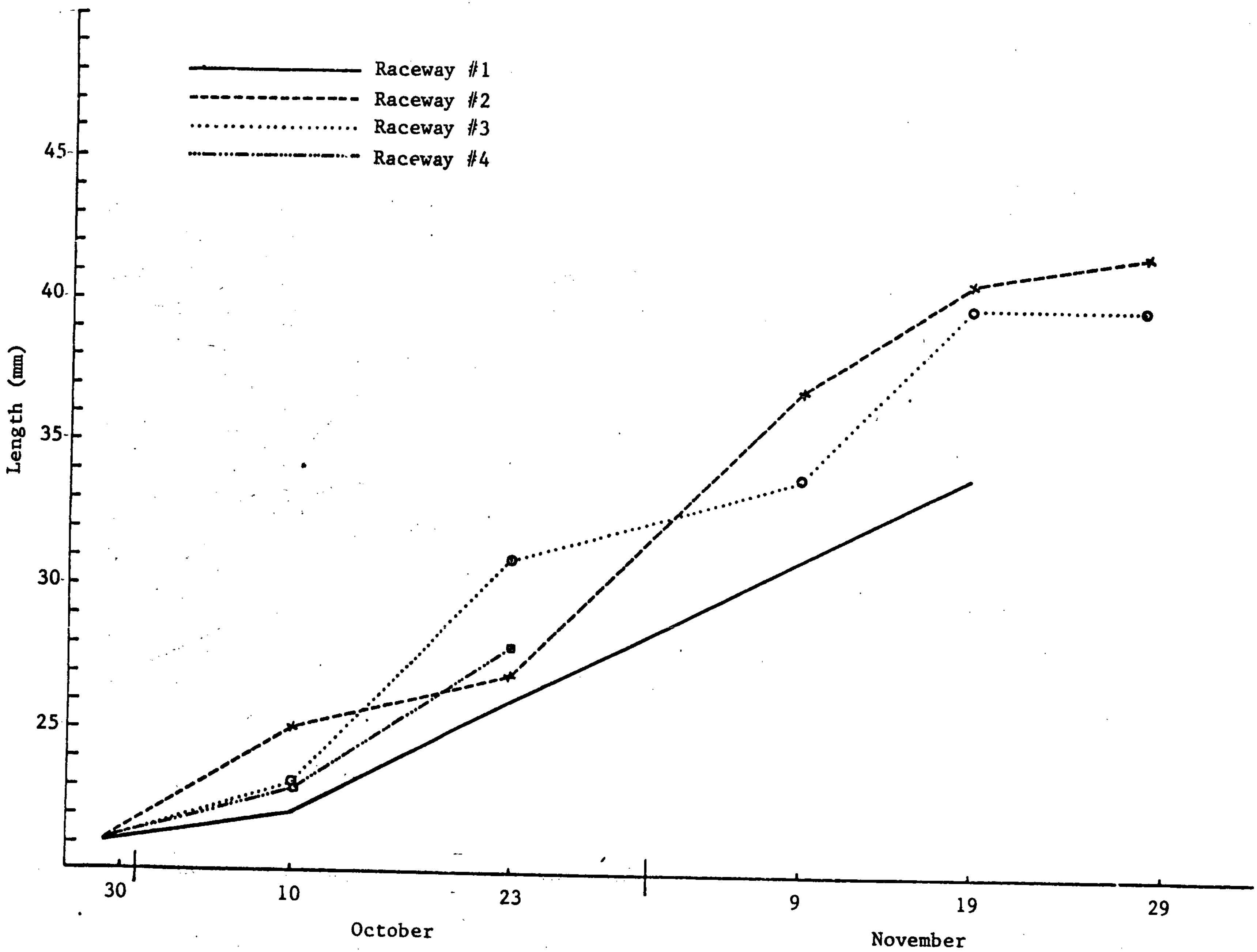


Fig. 3.1. Prawn growth in weight at four flow rates and stocking densities at the Raft River Geothermal Site.

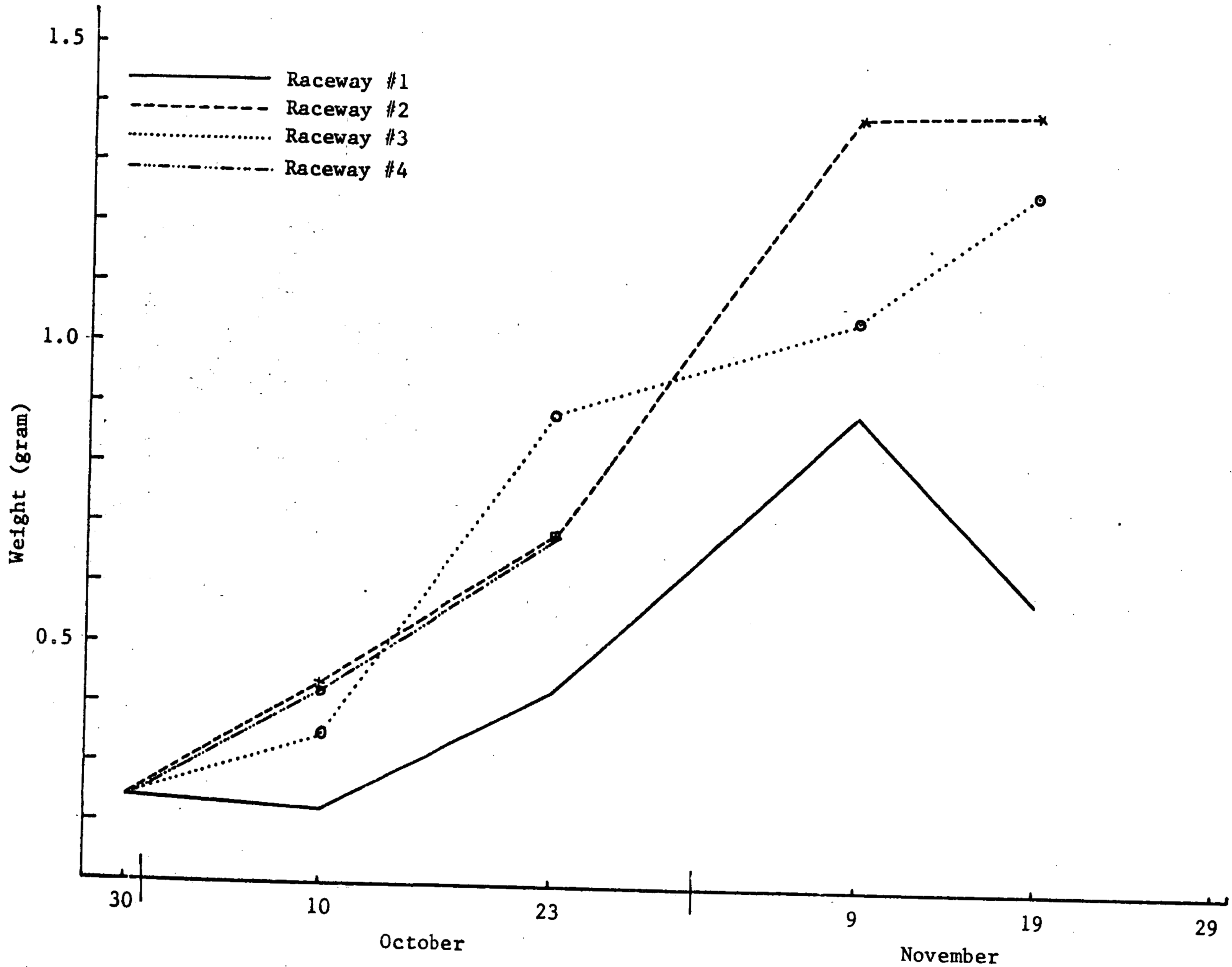


Fig. 3.2. Linear regressions of weight v. time for *Macrobrachium rosenbergii* at the ERDA RRGT. Flow rates (gpm) are: Tank 1 - 0.04, Tank 2 - 0.31, and Tank 3 - 0.11.

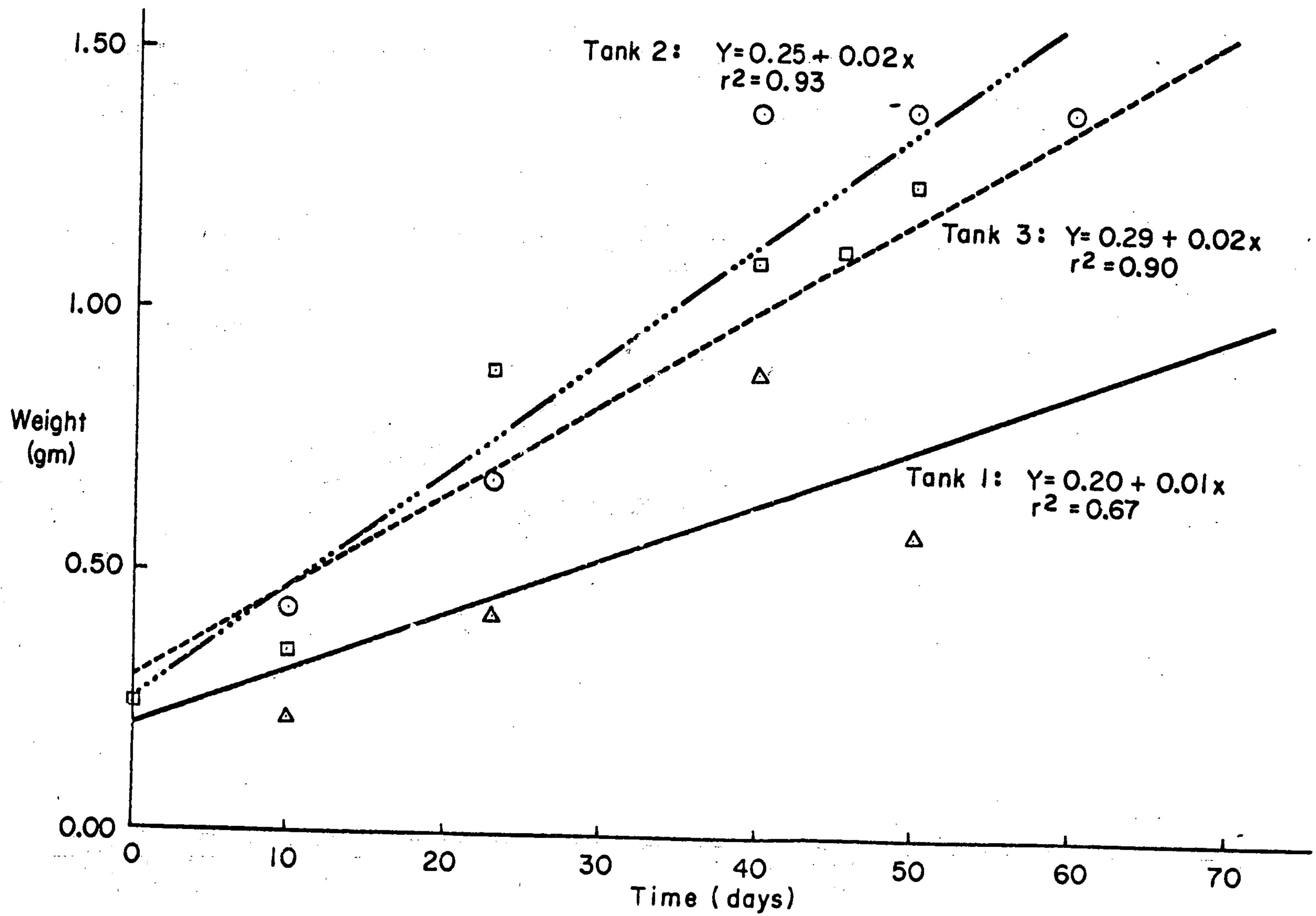


Fig. 3.3. Linear regressions of length v. time for Macrobrachium rosenbergii at the ERDA RRGT. Flow rates (gpm) are: Tank 1 - 0.04, Tank 2 - 0.31, and Tank 3 - 0.11.

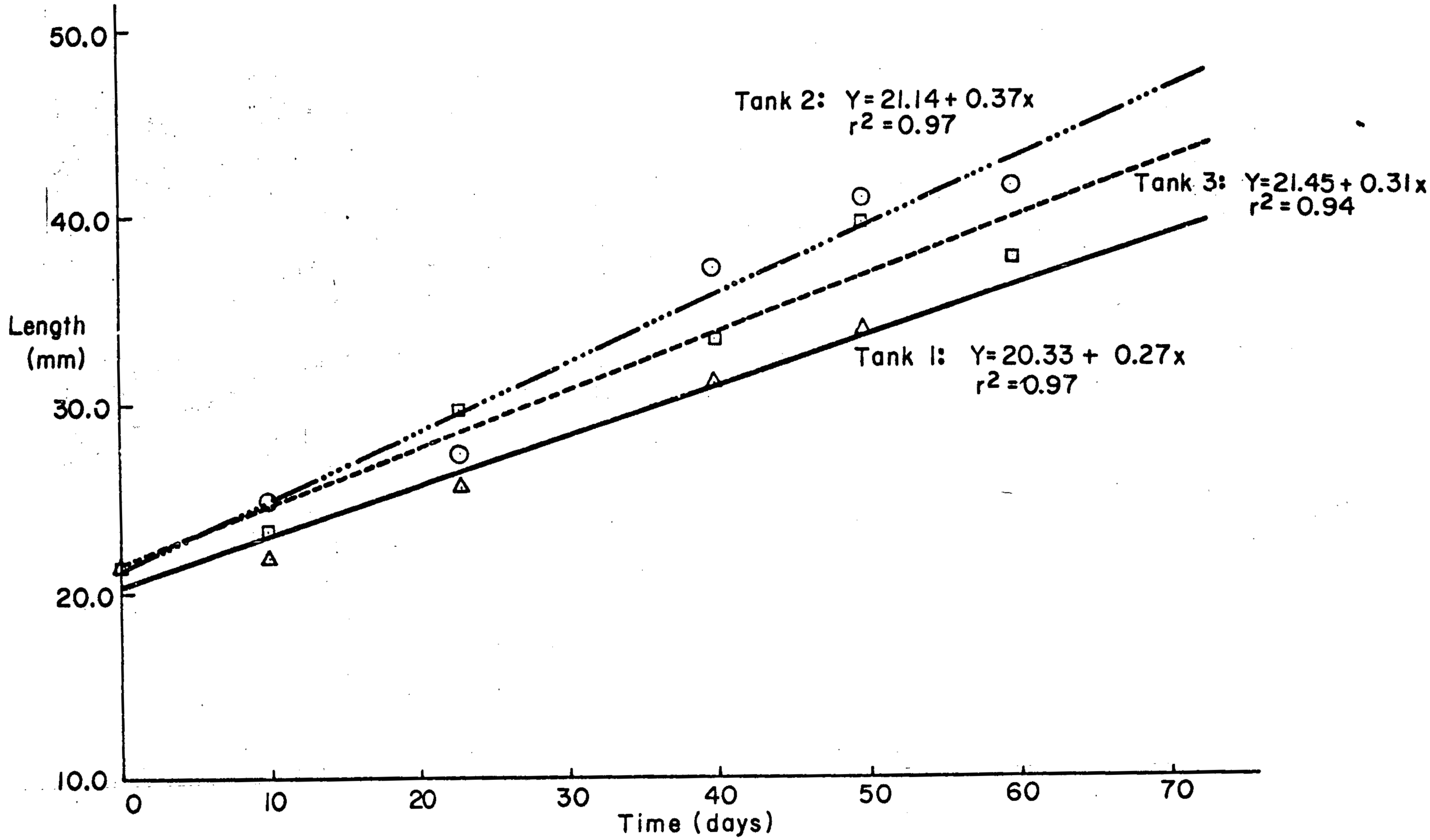


Fig. 3.4. Linear regressions of length and weight v. time for Macrobrachium rosenbergii in Tank 4 at the ERDA RRGT. The flow rate is 0.52 gpm.

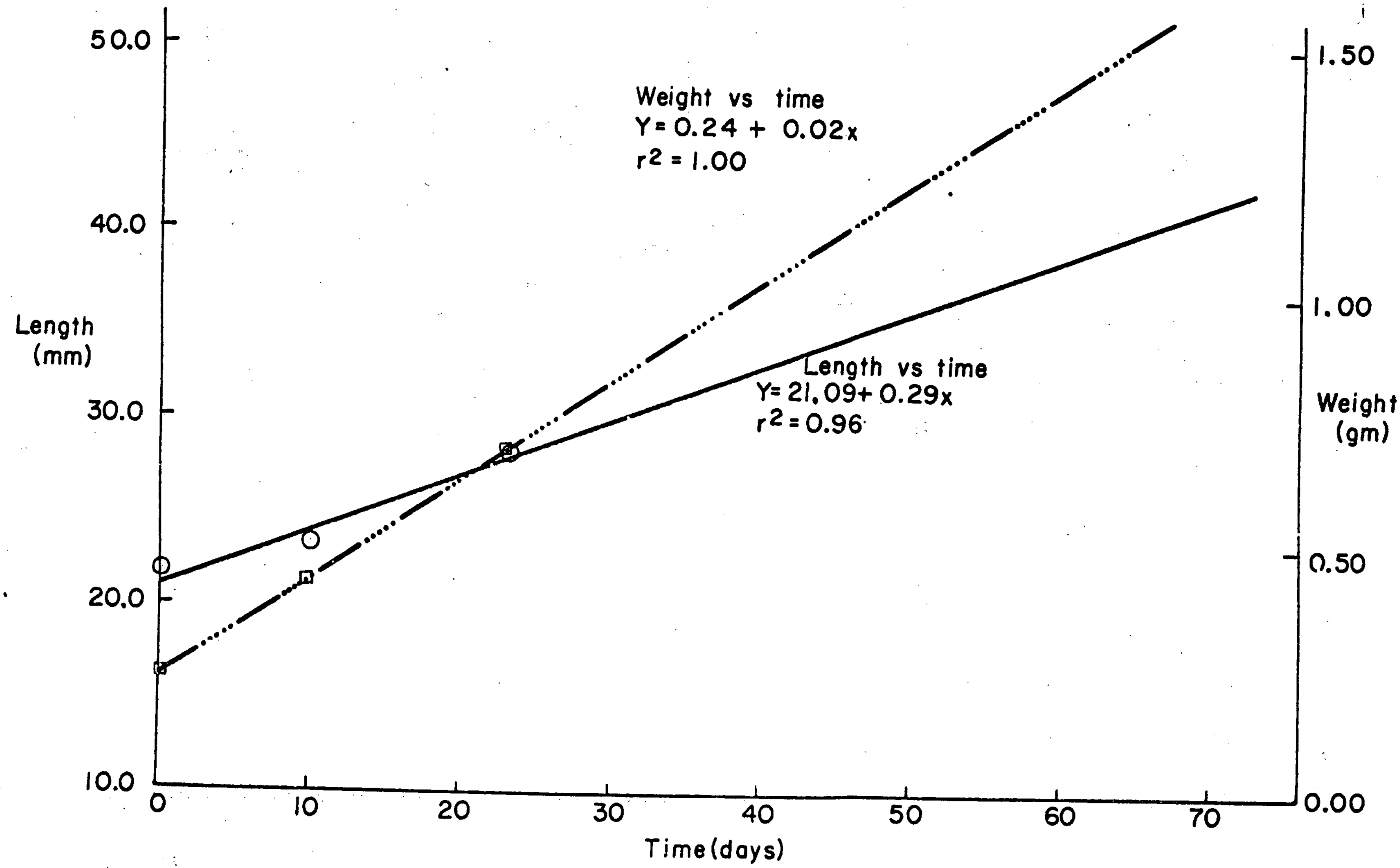


Table 4. Temperatures of low and high flow raceways at the ERDA RRGT over the experimental period. Recorded is the maximum, minimum, and average temperature (°F) for each day. Turnover times are: low flow - 90 min., high flow - 10 min.

	LOW FLOW			HIGH FLOW				LOW FLOW			HIGH FLOW		
DAY	max.	min.	ave.	max.	min.	ave.	DAY	max.	min.	ave.	max.	min.	ave.
1	79.1	77.8	78.5	81.5	81.0	81.3	16	---	---	---	---	---	---
2				81.0	80.0	80.5	17	---	---	---	---	---	---
3				81.0	80.0	80.5	18	72.0	72.0	72.0	79.0	75.0	77.0
4				80.5	80.5	80.5	19	78.0	78.0	78.0	78.0	78.0	78.0
5				80.0	80.0	80.0	20	72.0	72.0	72.0	74.0	74.0	74.0
6				70.0	70.0	70.0	21	77.5	73.0	75.3	77.3	76.0	76.6
7				76.0	76.0	76.0	22	---	---	---	---	---	---
8				78.0	78.0	78.0	23	---	---	---	---	---	---
9				80.0	80.0	80.0	24	71.7	69.4	71.1	73.9	73.8	73.5
10				82.0	82.0	82.0	25	80.2	65.0	72.6	81.0	72.7	76.9
11				84.0	78.0	81.0	26	75.8	73.0	74.2	76.5	76.0	76.3
12				79.0	79.0	79.0	27	78.2	78.0	78.1	80.0	75.3	77.7
13				79.0	78.0	78.5	28	83.3	83.3	83.3	79.2	79.2	79.2
14	80.0	79.0	79.5	82.0	80.0	81.0	29	80.0	79.0	79.5	88.0	82.0	85.0
15	80.0	79.0	79.5	79.5	78.0	78.8	30	79.0	73.0	76.0	82.0	77.0	79.5

Table 4 (continued):

31	79.8	73.0	76.4	80.5	78.0	79.3	49	85.7	62.0	73.9	87.6	66.0	76.9
32	81.0	76.5	78.8	79.8	76.0	77.7	50	89.9	71.5	80.7	94.4	73.5	83.5
33	78.3	69.5	73.9	78.9	76.0	77.5	51	85.8	74.7	80.3	91.6	91.1	91.4
34	79.5	72.0	75.8	76.0	76.0	76.0	52	90.2	68.0	79.1	96.1	85.0	90.6
35	75.0	73.0	74.0	69.0	68.0	68.5	53	73.0	68.0	70.5	73.0	70.0	71.5
36	81.5	81.0	81.3	76.8	76.0	76.4	54	75.0	72.0	73.5	75.0	72.0	73.5
37	79.0	70.0	74.5	80.0	69.0	74.5	55	72.0	68.0	70.0	74.0	72.0	73.0
38	69.0	69.0	69.0	71.0	71.0	71.0	56	72.0	68.0	70.0	74.0	72.0	73.0
39	79.6	67.0	73.3	80.2	69.0	74.6	57	84.0	76.0	80.0	82.0	76.0	79.0
40	69.5	69.5	69.5	71.5	71.5	71.5	58	79.0	75.0	77.0	82.0	78.0	80.0
41	69.3	69.1	69.2	72.1	71.1	71.6	59	80.0	68.0	74.0	80.0	79.0	79.5
42	68.0	68.0	68.0	70.2	69.0	69.6	60	79.0	70.0	74.5	82.0	76.0	79.0
43	67.0	66.0	66.5	68.0	67.0	67.5	61	82.0	74.0	78.0	87.0	74.0	80.5
44	60.0	60.0	60.0	61.0	60.0	60.5	62	78.0	74.0	76.0	81.0	81.0	81.0
45	67.0	66.0	66.5	70.0	69.0	69.5	63	76.0	74.0	75.0	82.0	82.0	82.0
46	66.0	66.0	66.0	70.0	70.0	70.0	64	78.0	76.0	77.0	84.0	82.0	83.0
47							65	77.0	76.0	76.5	82.0	80.0	81.0
48	76.0	74.2	75.3	81.1	78.0	79.6	66	82.0	69.0	75.5	82.0	68.0	75.0

Table 4 (continued):

67	77.0	64.0	71.5	80.0	77.0	78.5	85	74.0	66.0	70.0	82.0	80.0	81.0
68	82.0	68.0	76.0	82.0	68.0	75.0	86	76.0	67.0	71.5	84.0	80.0	82.0
69	74.0	72.0	73.0	80.0	80.0	80.0	87	79.0	68.0	73.5	84.0	82.0	83.0
70	74.0	72.0	73.0	80.0	74.0	77.0	88	76.0	68.0	72.0	84.0	80.0	82.0
71	78.0	74.0	76.0	85.0	84.0	84.5	89	74.0	66.0	70.0	82.0	80.0	81.0
72	79.0	72.0	75.5	82.0	80.0	81.0	90	75.0	64.0	69.5	84.0	82.0	83.0
73	76.0	70.0	73.0	83.0	81.0	82.0	91	82.0	70.0	76.0	90.0	70.0	80.0
74	78.0	54.0	66.0	84.0	80.0	82.0	92	86.0	69.0	76.5	84.0	78.0	81.0
75	74.0	73.0	73.5	84.0	81.0	82.5	93	80.0	64.0	72.0	83.0	80.0	81.5
76	82.0	62.0	72.0	86.0	82.0	84.0	94	76.0	62.0	69.0	82.0	81.0	81.5
77	80.0	66.0	73.0	80.0	78.0	79.0	95	78.0	60.0	69.0	86.0	84.0	85.0
78	80.0	68.0	74.0	80.0	74.0	77.0	96	78.0	60.0	69.0	82.0	40.0	61.0
79	72.0	66.0	69.0	82.0	77.0	79.5	97	74.0	64.0	69.0	83.0	78.0	80.5
80	78.0	63.0	70.5	83.0	79.0	81.0	98	74.0	62.0	68.0	76.0	74.0	75.0
81	76.0	74.0	75.0	86.0	82.0	84.0							
82	78.0	74.0	76.0	86.0	85.0	85.5							
83	72.0	68.0	70.0	82.0	80.0	81.0							
84	78.0	68.0	73.0	80.0	80.0	80.0							

Fig. 4.1. Temperature regime in high flow fish raceways at the ERDA RRGT over the experimental period. Data plotted is the average temperature on every third day. Fig. A.1 is the change in weight with time for Channel Catfish and Fig. B.1 is the change in weight with time for Tilapia in high flow.

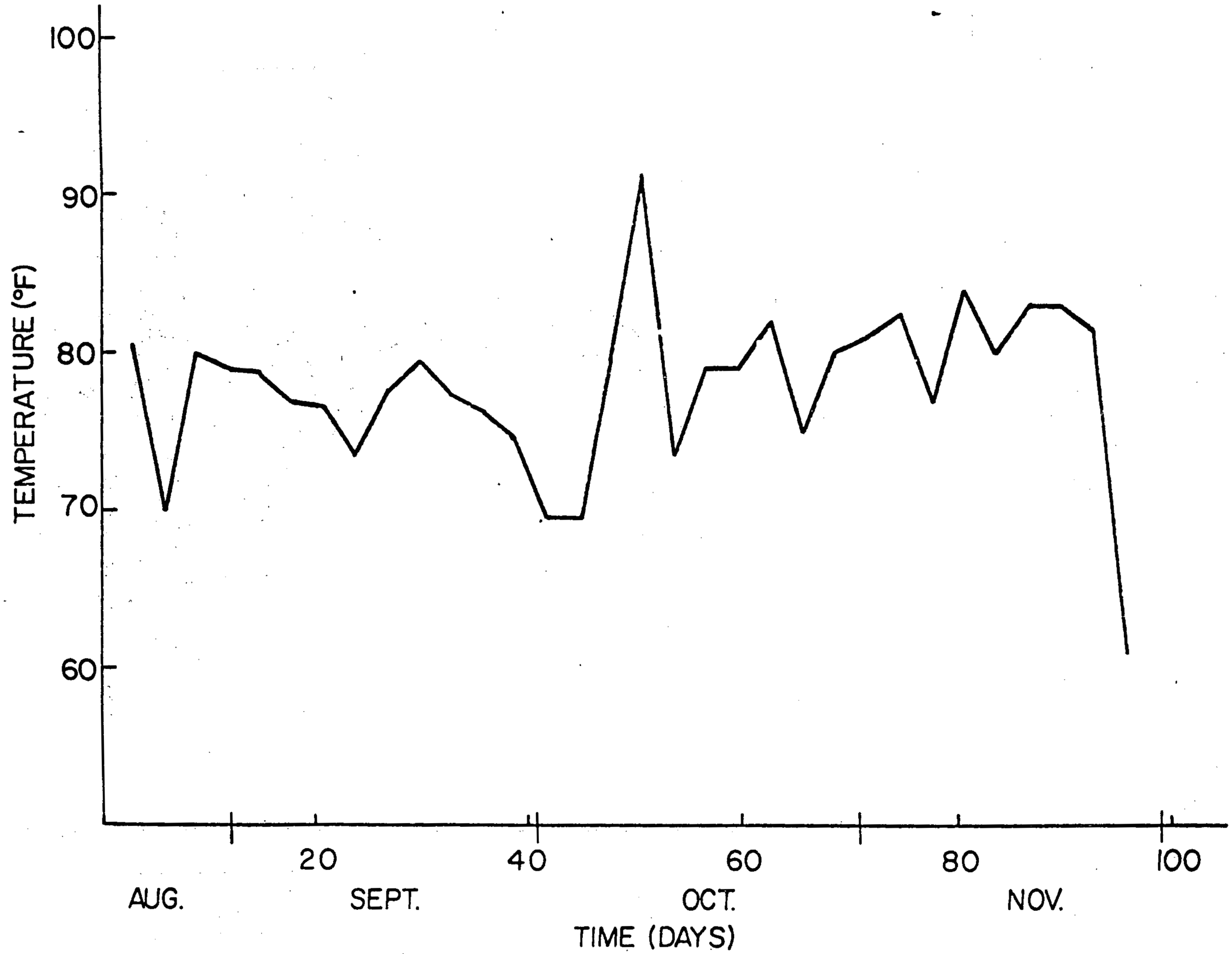


Fig. 4. Temperature regime in low flow raceways at the ERDA RRGT over the experimental period. Data plotted is the average temperature on every third day. The optimum is indicated. Fig. A is the change in weight with time for Channel Catfish (tank 2A) and Fig. B is the change in weight for Tilapia (tank 3A) in low flow tanks.

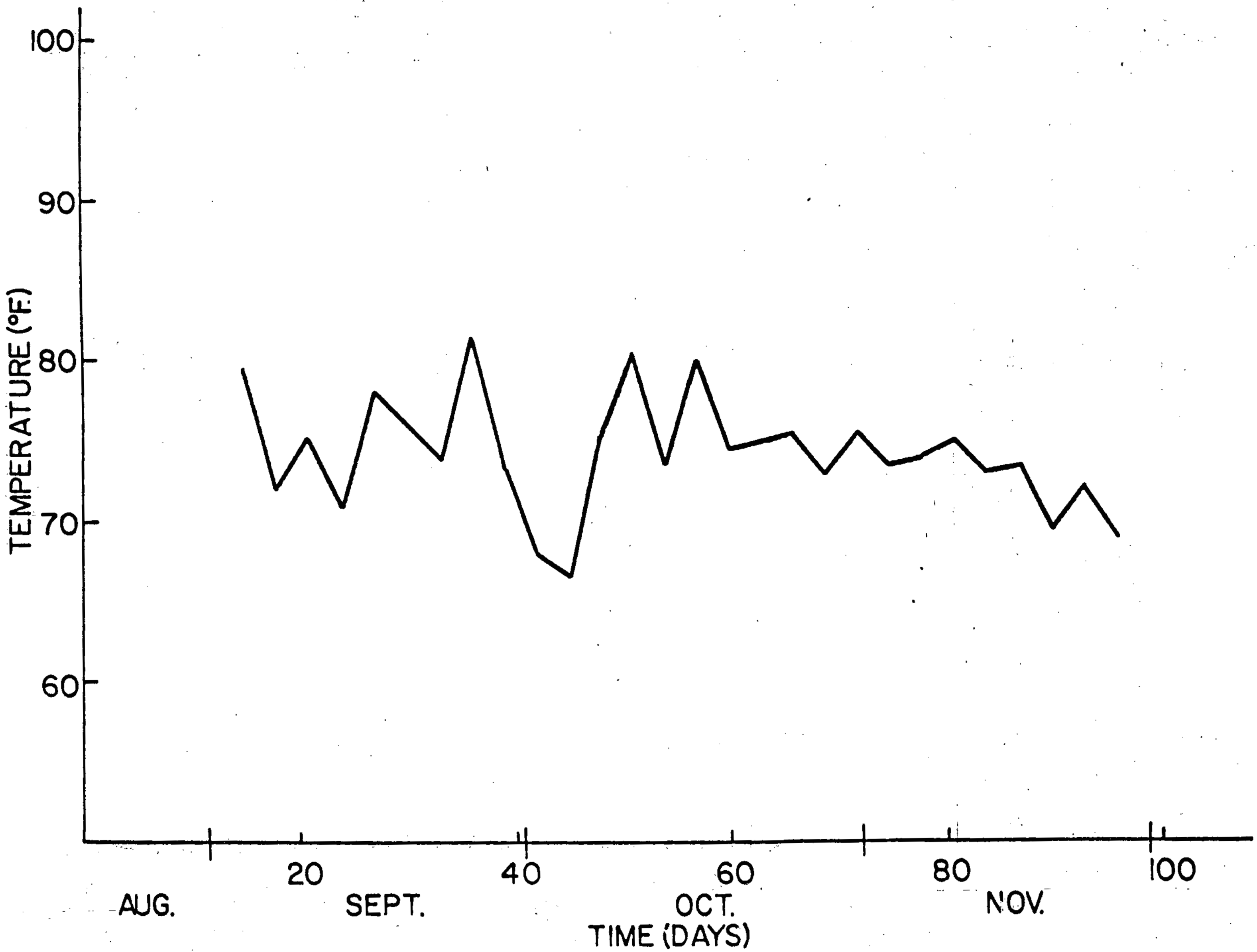


Fig. A.

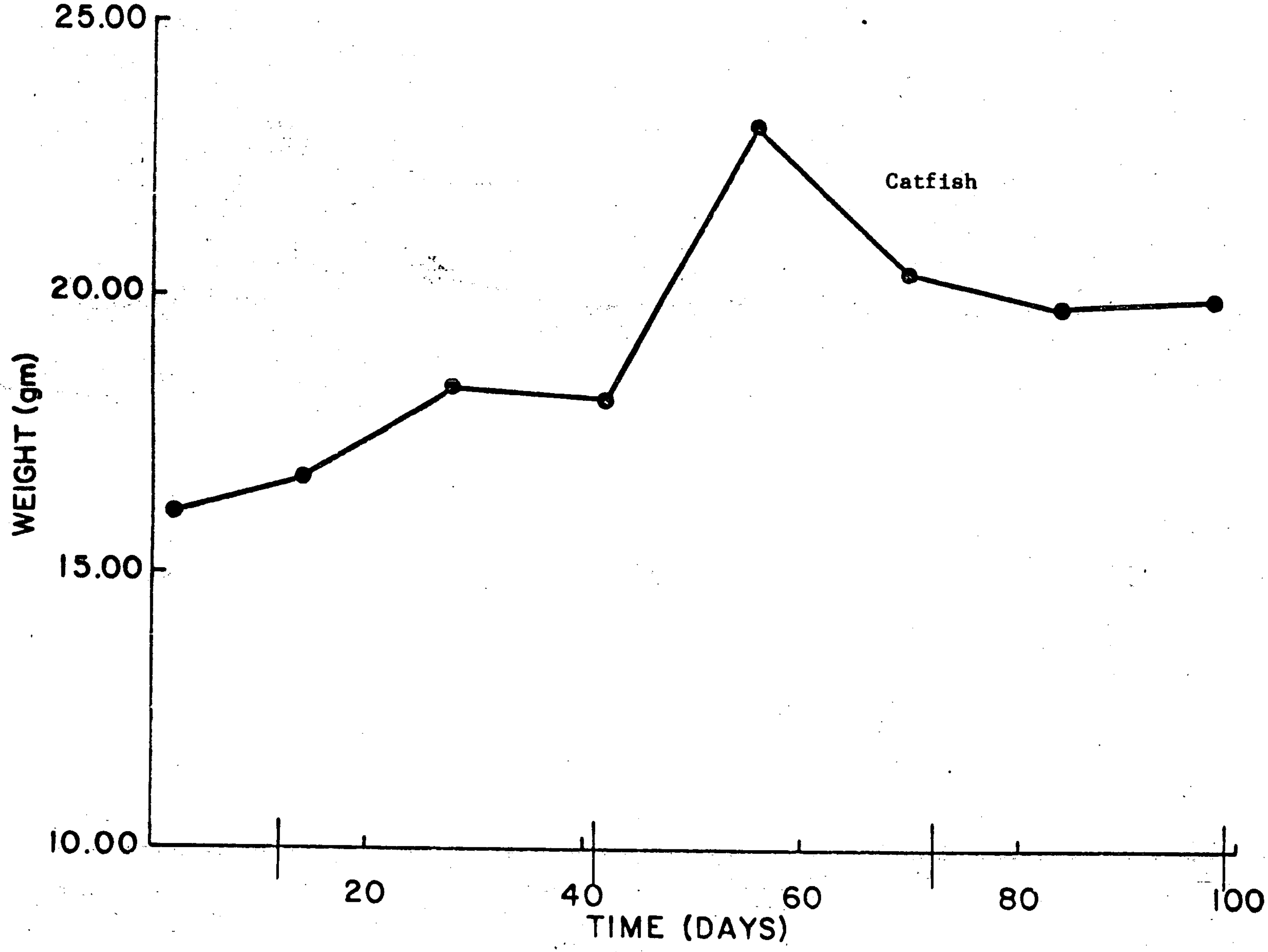
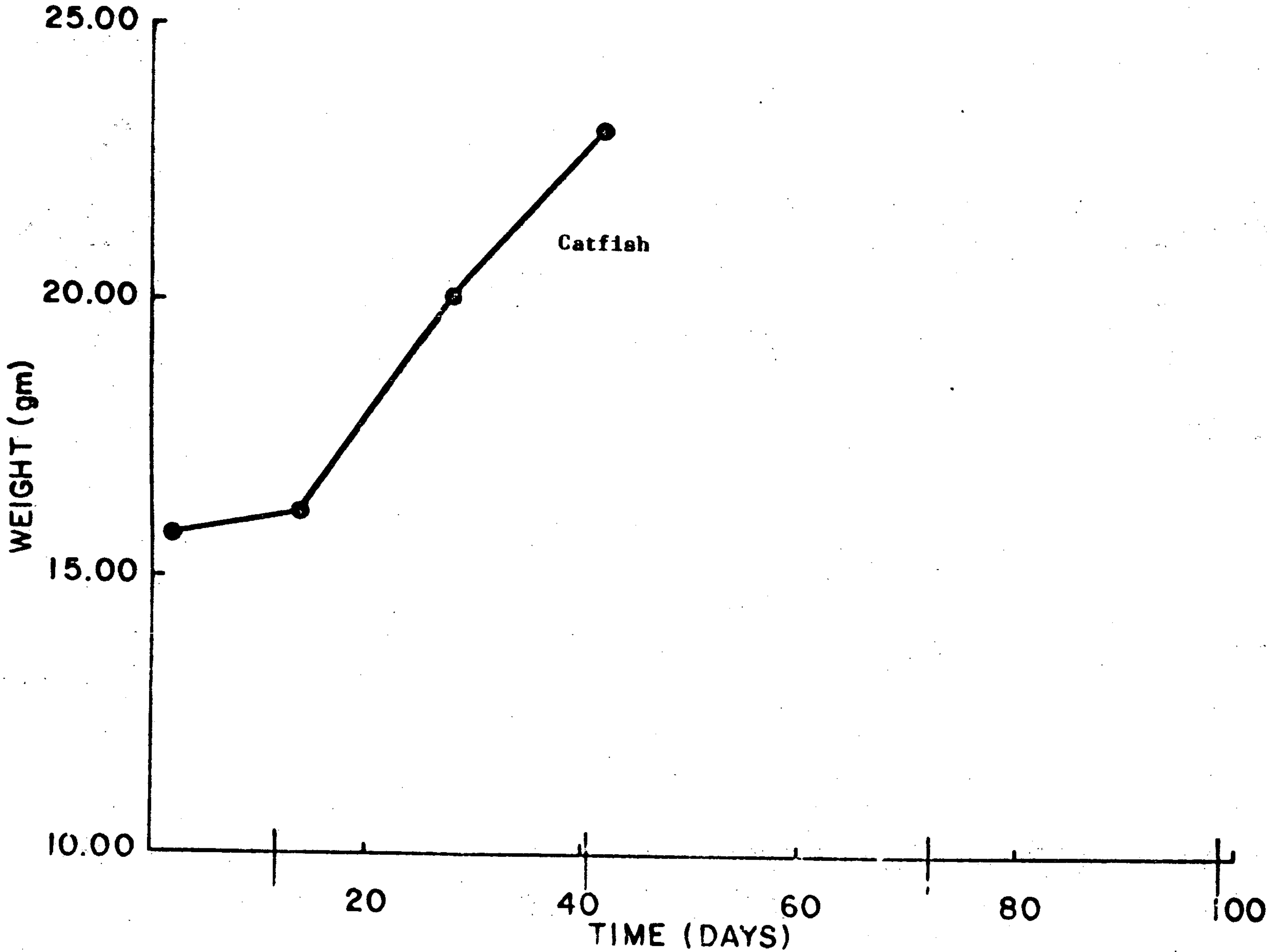

25.00
20.00
15.00
10.00
WEIGHT (gm)
Catfish
20
40
60
80
100
TIME (DAYS)

Fig. A.1.



25.00
20.00
15.00
10.00
WEIGHT (gm)
Catfish
20
40
60
80
100
TIME (DAYS)

Fig. B.

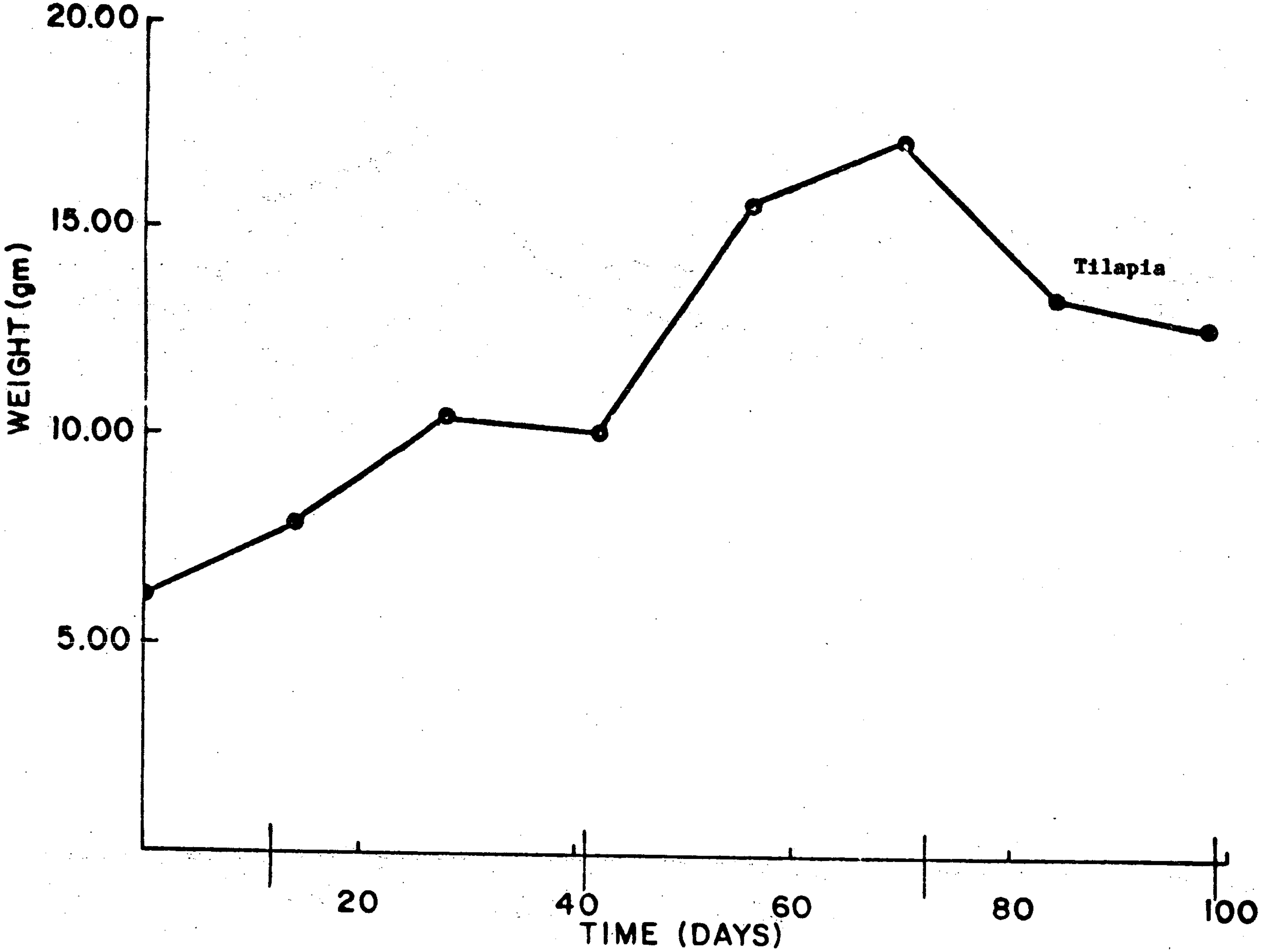


Fig. B.1.

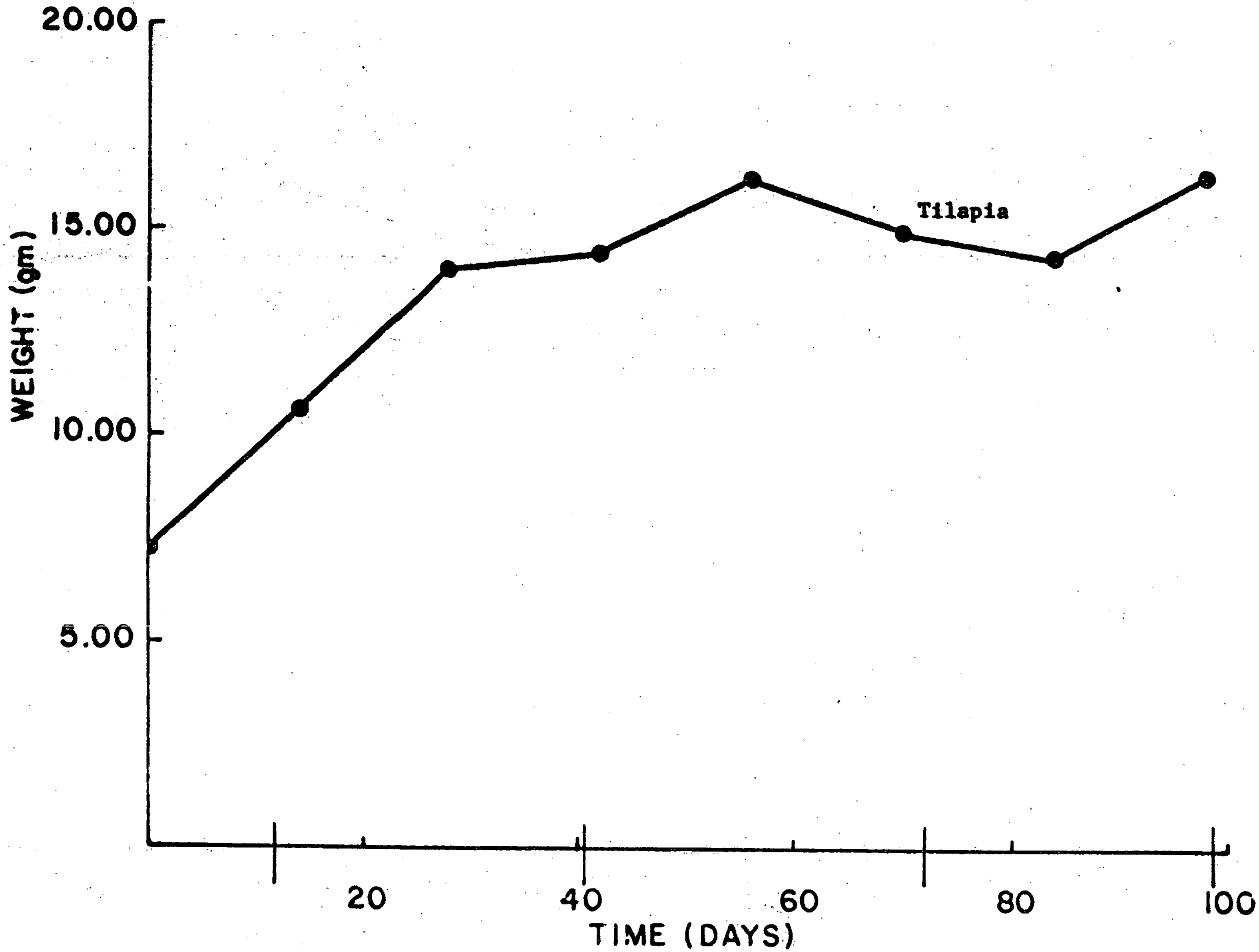


TABLE 5

PERCENT COLLAGEN CONTENT OF VERTEBRAL BONE IN THE CHANNEL CATFISH *Ictalurus punctatus*, AT THE ERDA RRGT AND BUHL, IDAHO. 3/

DATE	water source	RRGT		BUHL
	turnover time (min)	90	10	6
9-03		25.96 ± 0.28 (6)	25.80 ± 0.47 1/ (6) 2/	
9-10				25.76 ± 0.52 (6)
10-01			26.14 ± 0.20 (5)	
10-08				25.75 ± 0.16 (8)
10-15		26.12 ± 0.26 (6)		
11-26		23.60 ± 0.41 4/ (9)		
12-03				25.98 ± 0.20 (5)

1/ mean ± 1 standard error

2/ sample size in parentheses

3/ statistics: Analysis of variance $\alpha = 0.05$

4/ significant difference

TABLE 5.1

PERCENT COLLAGEN CONTENT OF VERTEBRAL BONE IN *Tilapia zillii* AT THE ERDA RRGT AND BUHL, IDAHO. 3/

DATE	water source: RRGT		BUHL
turnover time (min)	90	10	12
8-20			22.12 ± 1.28 1/ (8) 2/
9-03	22.73 ± 0.44 (5)	22.87 ± 0.98 (6)	
10-08			21.75 ± 0.22 (8)
10-15	21.79 ± 0.24 (6)	21.59 ± 0.37 (6)	
11-26	21.06 ± 0.52 (6)	21.04 ± 0.22 (4)	
12-03			20.87 ± 0.89 (4)

1/ mean ± 1 standard error

2/ sample size in parentheses

3/ statistics: Analysis of variance $\alpha = 0.05$

TABLE 6

FLUORIDE CONCENTRATION IN WHOLE BLOOD OF CHANNEL CATFISH AT THE ERDA RRGT AND CONTROL HATCHERY AT BUHL, IDAHO.

DATE	water source	RRGT		BUHL
	turnover time (min)	90	10	6
9-03		0.42 ± 0.08 1/ (7) 2/	0.48 ± 0.2 (11)	
9-10				0.23 ± 0.05 (10)
9-17		0.53 ± 0.08 (10)	0.36 ± 0.03 (10)	
10-01		0.87 ± 0.33 (10)	0.97 ± 0.31 (11)	
10-08				0.19 ± 0.02 (9)
10-15		0.36 ± 0.02 (8)		
10-29		0.37 ± 0.02 (11)		
11-05				0.21 ± 0.02 (10)
11-12		0.31 ± 0.03 (7)		
11-26		0.29 ± 0.03 (11)		

1/ mean ± 1 standard error

2/ sample size in parentheses

TABLE 6.1

FLUORIDE CONCENTRATION OF *TILAPIA ZILLII* AT THE ERDA RRGT. THIS IS PRELIMINARY DATA ONLY--THE REMAINDER IS FORTHCOMING. DATA PRESENTED IS FOR INDIVIDUAL FISH.

DATE	TURNOVER TIME(min)	FISH	FLUORIDE (mg/l)
11-12	90	1	0.37
		2	0.33
	10	1	0.20
		2	0.37
		3	0.33
		4	0.25
11-26	90	1	0.26
		2	0.36
		3	0.62
	10	1	0.17
		2	0.66
		3	0.35

FIGURE 6
FLUORIDE CONCENTRATION IN WHOLE BLOOD OF CHANNEL CATFISH AT THE ERDA RRGT AND CONTROL HATCHERY AT BUHL, IDAHO.

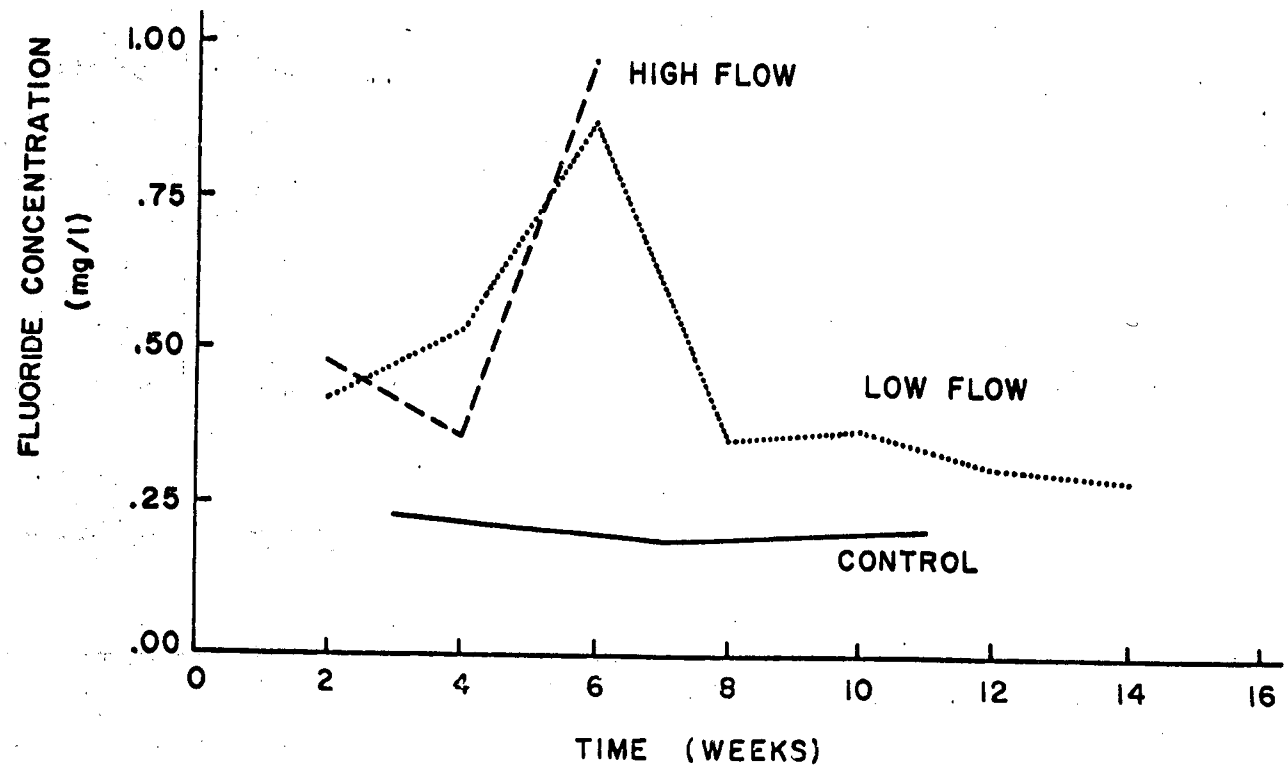


Table 7. Tissue residues of heavy metals present in the geothermal waters of the ERDA RRGT. Values are expressed as ug/g.

SPECIES	DATE	SOURCE	Mercury Hg	Cadmium Cd	Copper Cu	Lead Pb	Manganese Mn	Zinc Zn	Arsenic As
Channel Catfish *Ictalurus punctatus*	9-10	Buhl	0.23 ± 0.05 (6)	ND 1/ (6) 2/	ND (6)	ND (6)	ND (6)	ND (6)	ND (3)
	9-17	RRGT	0.27 + 0.12 (6)						
	10-08	Buhl	0.10 ± 0.03 (6)						
	10-15	RRGT	0.16 ± 0.02 (6)						
	11-26	RRGT	0.22 ± 0.08 (6)	ND (6)	ND (6)	ND (6)	ND (6)	ND (6)	ND (3)
	12-03	Buhl	0.17 ± 0.04 (6)	ND (6)		ND (6)		ND (6)	
Tilapia zillii	8-26	Buhl		ND (6)	ND (6)	ND (6)	ND (6)	ND (6)	ND (3)
	9-10	Buhl	0.21 ± 0.04 (6)	ND (6)		ND (6)		ND (6)	
	9-17	RRGT	0.37 ± 0.04 (6)						
	10-08	Buhl	0.45 ± 0.05 (6)						
	10-15	RRGT	0.57 ± 0.05 (6)						
	11-26	RRGT	0.24 ± 0.07 (6)	ND (12)	ND (6)	ND (12)	ND (6)	ND (12)	ND (3)
	12-03	Buhl	0.41 ± 0.10 (6)	ND		ND		ND	
Macrobrachium rosenbergii	10-09	RRGT		ND (10)		ND (10)		ND (10)	
	11-29	RRGT	0.12 ± 0.05 (13)	ND (13)	ND (6)	ND (13)	ND (6)	ND (13)	

1/ not detectable
2/ sample size in parentheses

Figure 7. Tissue mercury levels in Channel Catfish and Tilapia at the Raft River Geothermal Site and Buhl control facility.