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Assimilation, Metabolism and Growth of Utah Chub, Gila Atraria

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ABSTRACT

The growth, assimilation and metabolism of Utah chub, *Gila atraria*, was assessed in laboratory tanks at four rates of food intake and at four temperatures. Growth of chub increased as temperature and food intake increased and a smaller percentage of the food ended up as excreta. Metabolic rate was influenced primarily by food intake rather than temperature.

INTRODUCTION

During 1971-72, the growth of Utah chub, *Gila atraria*, was assessed in laboratory tanks with four levels of food intake and four temperatures. This study was undertaken to define some of the processes (namely growth, assimilation and metabolism of Utah chub) operating in one of the aquatic study sites of the IBP Desert Biome.

Fish for these tests were collected in Off Spring, one of the springs at the Locomotive Springs area in northern Utah. Water temperatures in the spring ranged from 9°C in the winter to 16°C in summer. The fish were abundant and small (up to 9 cm total length) in the spring.

Initially the plan was to assess growth of three age groups of chub (young of year, juvenile and adults), but it was not possible to distinguish between the age groups and thus only the larger individuals were selected for testing. An attempt to assess growth at temperatures of 6 and 24°C indicated that fish did not respond to feeding in the lower temperature and died when held in the 24°C water. Mortality of fish transported to the laboratory at the University of Idaho was relatively high during the initial weeks of acclimation, and fish used in the tests were the survivors that had been treated with salt and malachite green.

The maximum rate of feeding at each temperature used in the tests was determined in preliminary feeding trials and approximates the maximum feeding rate at which all fish ate the food provided. The lowest intermediate feeding rates used in the test were arbitrarily selected.

METHODS

Utah chubs ranging from 5-9 cm were obtained from Locomotive Springs, Utah, on September 16, 1971. Upon arrival at the University of Idaho, they were subjected to a malachite green bath (0.75 ppm, 60 min.), followed by a salt solution dip (2%, 15 min.). They were then divided into four groups (8°C, 12°C, 16°C, 20°C) and were acclimated for four weeks. The mortality was about 40% in the first week and gradually dropped to virtually no loss in the fourth week.

Initially, growth of individual fish was assessed in separate test aquaria but most fish lost weight when tested individually, even when fed large food rations. When 4-5 fish were placed together in a larger aquaria the fish consumed the food provided and grew. The tests were conducted, therefore, with groups of fish in 80 l stainless steel tubs (0.13 - 0.34 grams of fish, wet weight,/liter) placed in a water bath to maintain the desired temperature (Fig. 1). All water used in the experiments was tap water kept in separate reservoirs, aerated and held at the test temperature. One-half to one-quarter of the water in each tub was changed daily depending on temperature and ration. Dissolved oxygen concentrations were maintained near saturation.

Four tubs were placed in each water bath, one for each food ration tested (Table 1). The food rations ranged from no food to intermediate levels of feeding and one level near the maximum amount the fish would eat.

After acclimation and just before the tests began, all fish were starved for three days. They were then weighed and the test begun.

In the preliminary studies it was found that the chubs preferred to feed on a commercial fish food (Oregon Moist Pellets) rather than beef liver, brine shrimp or freshwater amphipods (*Gammarus* sp.). Each daily ration was weighed after sitting in the open room for 1 hour following removal of the pellets from the freezer. The fish were fed once daily, and when on occasion all the food was not eaten it was removed before the next feeding. Pellets 3/22 inch in diameter were used to facilitate identification and removal of uneaten food from the tubs.

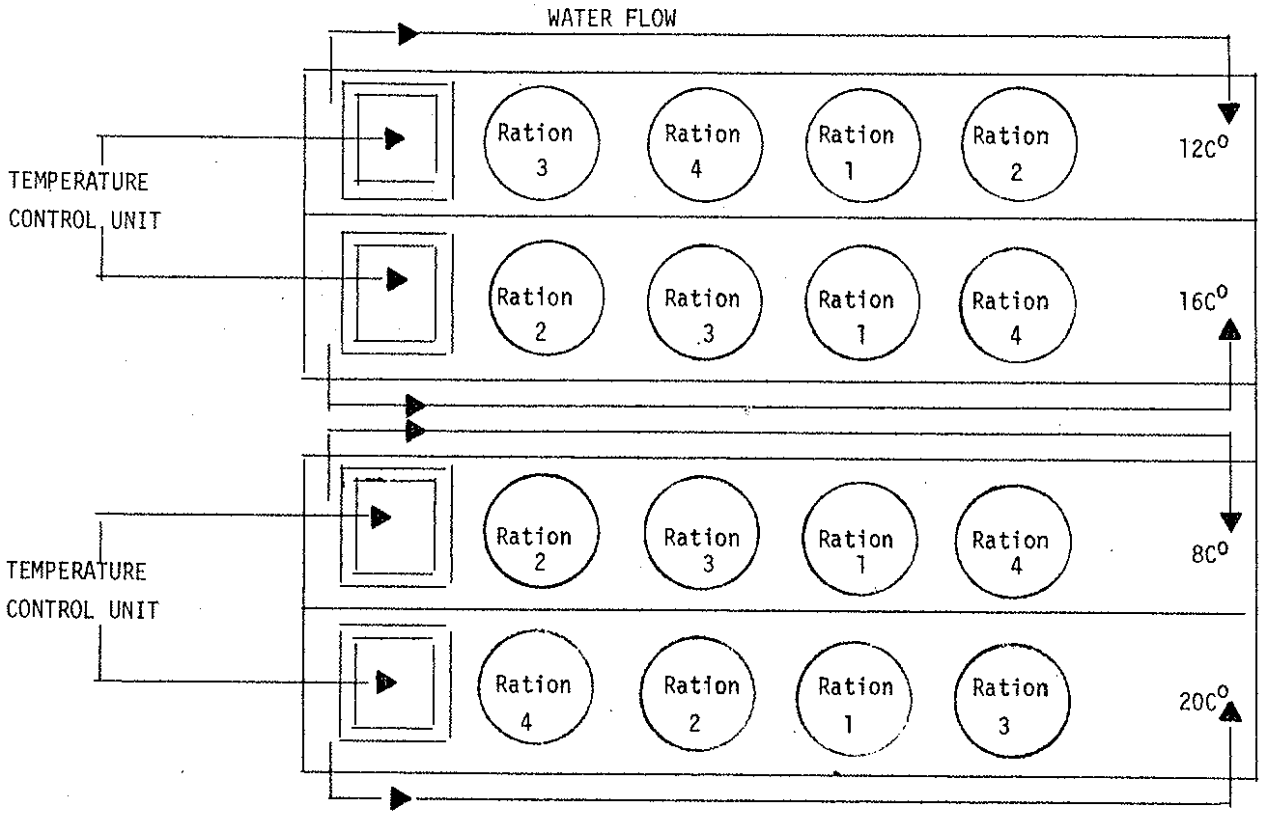

Figure 1. Water bath tables and tubs used for growth-metabolism tests with Utah chub

Table 1. Temperature and food rations and number of fish used in tests of Utah chub growth, metabolism and assimilation.

Temperature and ration	Number of fish in test	Mean Biomass (Kcal)	Food Ration: Cal of food per Kcal of fish per day	Food Ration: Food as percentage of body weight per day
8°C Ration 1	5	25.069	0	0
2	5	25.640	21.649	2.26
3	5	25.778	43.958	4.60
4	5	22.412	60.393	6.36
12°C Ration 1	5	14.342	0	0
2	5	34.045	34.928	3.47
3	3	33.803	65.640	6.85
4	5	25.825	94.259	9.89
16°C Ration 1	5	17.397	0	0
2	5	38.374	42.442	4.43
3	4	30.182	85.236	8.91
4	5	27.715	135.000	13.63
20°C Ration 1	5	17.679	0	0
2	5	31.987	81.411	8.51
3	5	28.505	161.230	16.87
4	4	25.923	204.565	21.46

At the end of the growth test period (36 days), fish were again starved for three days and weighed on the fourth day. Fish were weighed to the third decimal point in a pre-weighed volume of water on an electrical balance after excess body water had been absorbed on a damp tissue paper. The weight difference between the beginning and end of the test period was the growth.

Immediately after the growth tests, all tubs were cleaned and filled with fresh water for the tests designed to assess assimilation and metabolic rate. Fish used in the growth tests were placed in the tubs, fed the same ration as in the growth test for 2 days and then starved for 3 days. Fecal wastes were siphoned each day from the tubs, filtered, flashed with nitrogen, and stored in a glass jar at -20°C until analyzed. The remaining water in the tubs, containing the remainder of the fish wastes, was measured (volumetrically) and a representative sample (one l) stored in a brown polyethelene bottle at -10°C until analyzed.

The fecal matter was vacuum dried at 70°C for 48 hours, and weighed. Two representative portions were taken (8 to 20 mg), and their caloric values were determined by the wet combustion method (Karzinkin and Tarkovskaya, 1964). The frozen water samples which contained both dissolved food matter and dissolved fish wastes were freeze-concentrated at -10°C for 36 hours with a Wrist-Arm shaker (Shapiro, 1961). The concentrated water samples were transferred into a volumetric cylinder with several small portions of distilled water, and the volume measured. The caloric value was determined for two 10 ml samples as described in the fecal analysis.

To determine the relationship between dry and wet weight of food and fish, these materials were weighed to the nearest 5 mg after blotting. All materials except fish were oven-dried for 24 hr at 60°C. Fish were dried in a vacuum oven at 60°C for 48 hr. The relationship of dry to wet weight of 3/32 inch Oregon Moist Pellet was (Fig. 2):

$$y = -0.0006 + 0.7172x$$

In the data for Utah chub, two points appear erroneous (Fig. 3). These two determinations were not included and the following equation was used to describe the relationship:

$$y = -0.845 + 0.2462x$$

Dried materials were refined in a Wiley mill. Pellets, ranging from about 50 to 200 mg, were prepared with a Parr pellet press and combusted in a Parr semi-micro oxygen bomb calorimeter charged to 35 atm. to determine caloric values. Ash content as percentage of total dry weight was determined from samples of the materials after combustion in a furnace at about 800°C for 4 hr. Caloric values (Table 2) were corrected for ash content, environmental radiation, nitric acid formation and thermometer stem emergence.

The energy content (Kcal) of fish was calculated by multiplying the dry weight of fish by the average caloric content per gram of fish (5764 cal/gram dry weight, Table 2).

The energy of food ingested per Kcal of fish per day was obtained by multiplying the dry weight of the daily ration by its average caloric content (5472 cal per g ash free dry weight) and dividing by the caloric content (Kcal) of the fish in each tub.

Growth rates (cal/Kcal fish/day) were calculated by multiplying the daily weight gain (g ash-free dry weight/day) by the caloric content of the fish (5764 cal per g ash-free dry weight), then dividing by the caloric content of the fish in the tub.

Energy content of fecal and nitrogenous excreta (cal/Kcal fish/day) was calculated by multiplying the amount of oxygen used for the complete oxidation of the average daily fecal and nitrogenous excreta by the constant 3.42 (Warren and Davis, 1967) and then dividing by the caloric content of the fish.

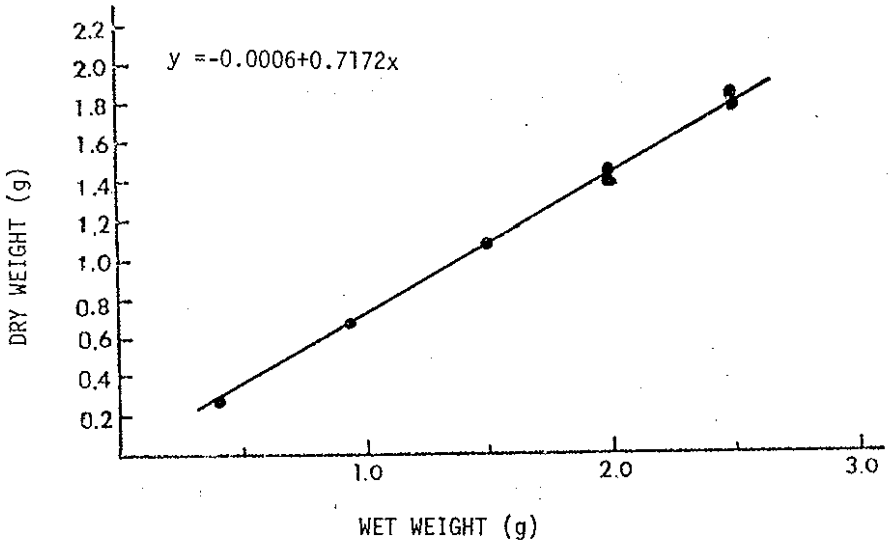

Figure 2. Wet-dry weight relationship for Oregon Moist Pellet fish food (3/32" diameter pellet).

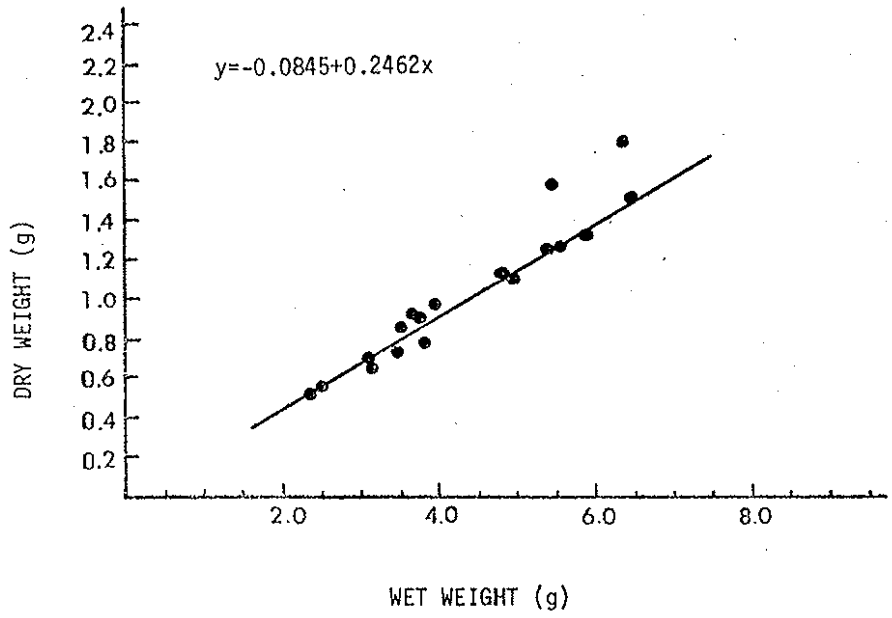

Figure 3. Wet-dry weight relationship for Utah chub.

Table 2. Range, mean and standard error of means of ash content as percentage of dry weight and caloric values per gram ash-free dry weight of food and Utah chub used in the experiment.

Material	Ash Content: No. of Samples	Percentage of dry weight: Range	Mean	S.E.	Kcal/Gram: No. of Samples	Ash-free Dry Weight: Range	Mean	S.E.
3/32" Food Pellet	3	9.34-9.86	9.52	0.14	6	5.417-5.576	5.472	0.020
Utah chub (Feb.)	2	15.58-15.90	15.74	--	3	5.662-5.946	5.810	0.067
Utah chub (June)	22	10.65-14.64	12.17	0.24	19	5.838-6.159	5.987	0.019
Utah chub (Sept.)	6	13.04-14.79	14.06	0.27	10	5.658-5.841	5.764	0.015

Metabolic rates (cal/Kcal/day) were calculated by subtracting the caloric values of the growth and fecal and nitrogenous excreta from the caloric value of the food-ingested ration.

Energy assimilated was calculated by subtracting the fecal and nitrogenous energy from that of food ration. Since this estimate of assimilated energy excluded the energy of nitrogenous wastes, it is less than the true assimilated energy.

Gross growth efficiency is determined by dividing the growth rate (cal/Kcal/day) by the food ration (cal/Kcal/day).

Data from these experiments are located in the central data bank under DSCODE A3UWC04.

FINDINGS

The food consumption rate, growth rate, metabolic rate and gross growth efficiency of fish were largest at 20°C and decreased at the lower temperatures (Table 3). Energy loss through fecal and nitrogenous excreta was largest (on a percentage of food consumption) at the lowest temperatures. The metabolic rate of the starved fish was 1-5 percent of the fed-fish, depending on the water temperature and ration consumed.

The relationship between food intake, temperature and growth rate (Fig. 4) suggests that growth of chub was affected by both food intake and temperature. At a given food intake, fish grew most in 20°C water with less growth by fish at 16°C and 12°C, and a loss of weight by fish at 8°C.

Both temperature and food intake also affect the gross growth efficiency of the fish (Fig. 5). The percentage of food intake converted into fish growth increased with temperature. At the three higher temperatures at which growth occurred, there was a negetive relationship between food intake and growth efficiency. At the lowest temperature there was a positive slope to the food intake-growth relationship.

Table 3. Growth, assimilation, metabolism and growth efficiency of Utah chub at four temperatures and food intake levels. All values express in caloric energy equivalents.

Temperature and food ration	Mean biomass of fish in test (Kcal)	Food Consumed (cal) per Kcal fish per day	Fish wastes & dissolved food (cal) per Kcal fish per day	Food assimilated (%)	Growth (cal) per Kcal fish per day	Metabolism (cal) per Kcal fish per day	Gross efficiency growth/food (%)
8°C							
Ration 1	25.069	0	0.09	-----	-0.892	0.80	----
2	25.640	21.649	3.11	85.64	-0.492	19.03	2.27
3	25.778	43.958	3.47	92.11	-0.908	41.40	2.07
4	22.418	60.393	6.11	89.88	-0.644	54.92	1.07
12°C							
Ration 1	14.342	0	0.20	-----	-1.732	1.53	----
2	34.045	34.928	3.94	88.72	0.475	30.51	1.36
3	33.803	65.640	5.38	91.80	1.105	59.15	1.68
4	25.825	94.259	8.79	90.67	1.317	84.15	1.40
16°C							
Ration 1	17.397	------	0.16	-----	-1.90	1.74	----
2	38.374	42.442	4.85	88.57	1.057	36.53	2.49
3	30.182	85.236	7.96	90.66	2.446	74.83	2.87
4	27.715	135.00	9.81	92.73	2.344	122.85	1.74
20°C							
Ration 1	17.679	0	0.19	-----	-1.866	1.68	----
2	31.987	81.411	4.56	94.40	4.529	72.33	5.55
3	28.505	161.230	9.02	94.41	5.005	147.20	3.10
4	25.923	204.565	11.82	94.22	5.329	187.41	2.60

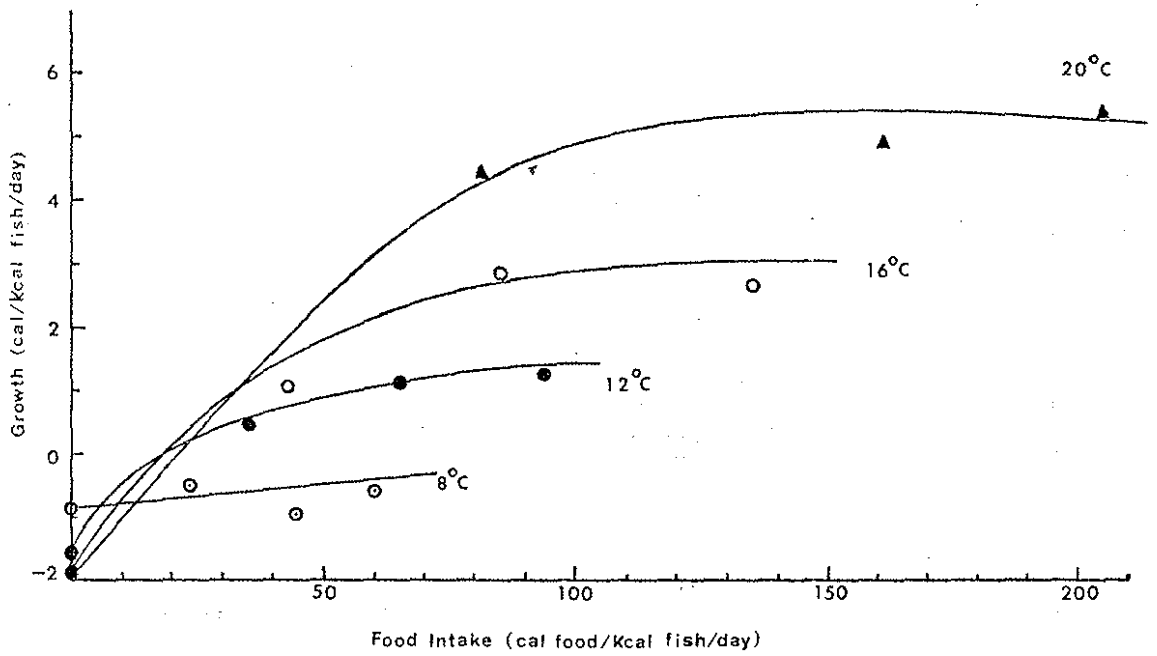

Figure 4. Growth of Utah chub at various temperatures and amounts of food intake.

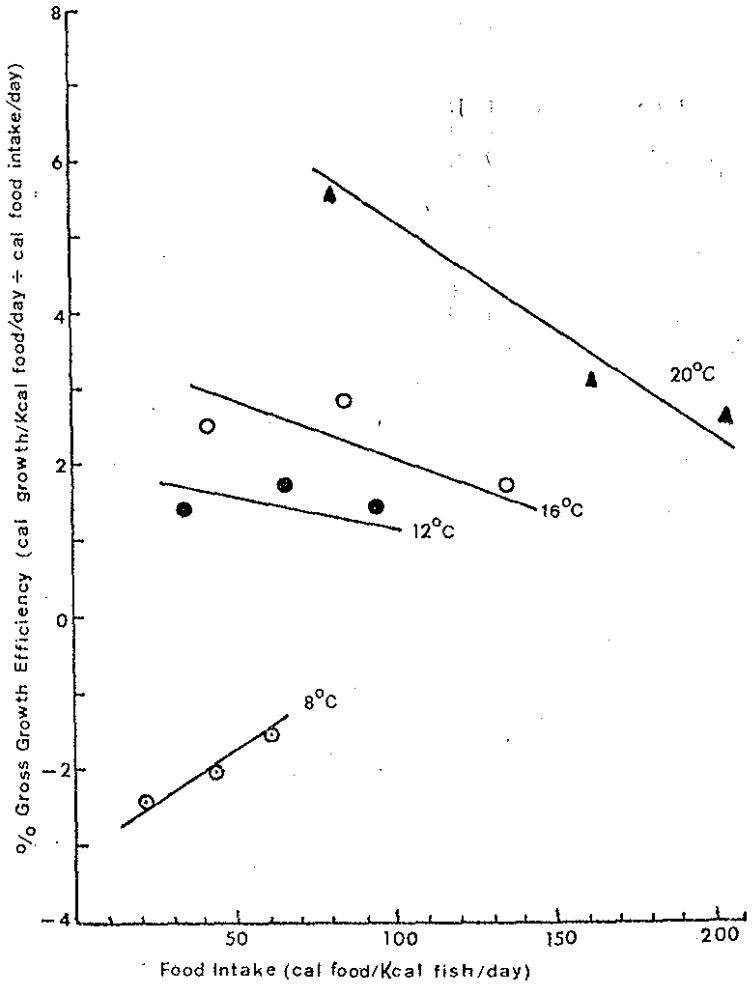

Figure 5. Percentage gross growth efficiency of Utah chub at various temperatures and amounts of food intake.

The caloric value of the fecal and nitrogenous excreta by chub for any given level of food intake was largest for fish in 8°C water, followed by fish in 12°C, 16°C, and 20°C water (Fig. 6). A relatively constant percentage of the food intake at each temperature was excreted by the chub. Thus the percentage of food excreted remained relatively constant at various rates of food intake at a given temperature, but increased at the lower temperatures.

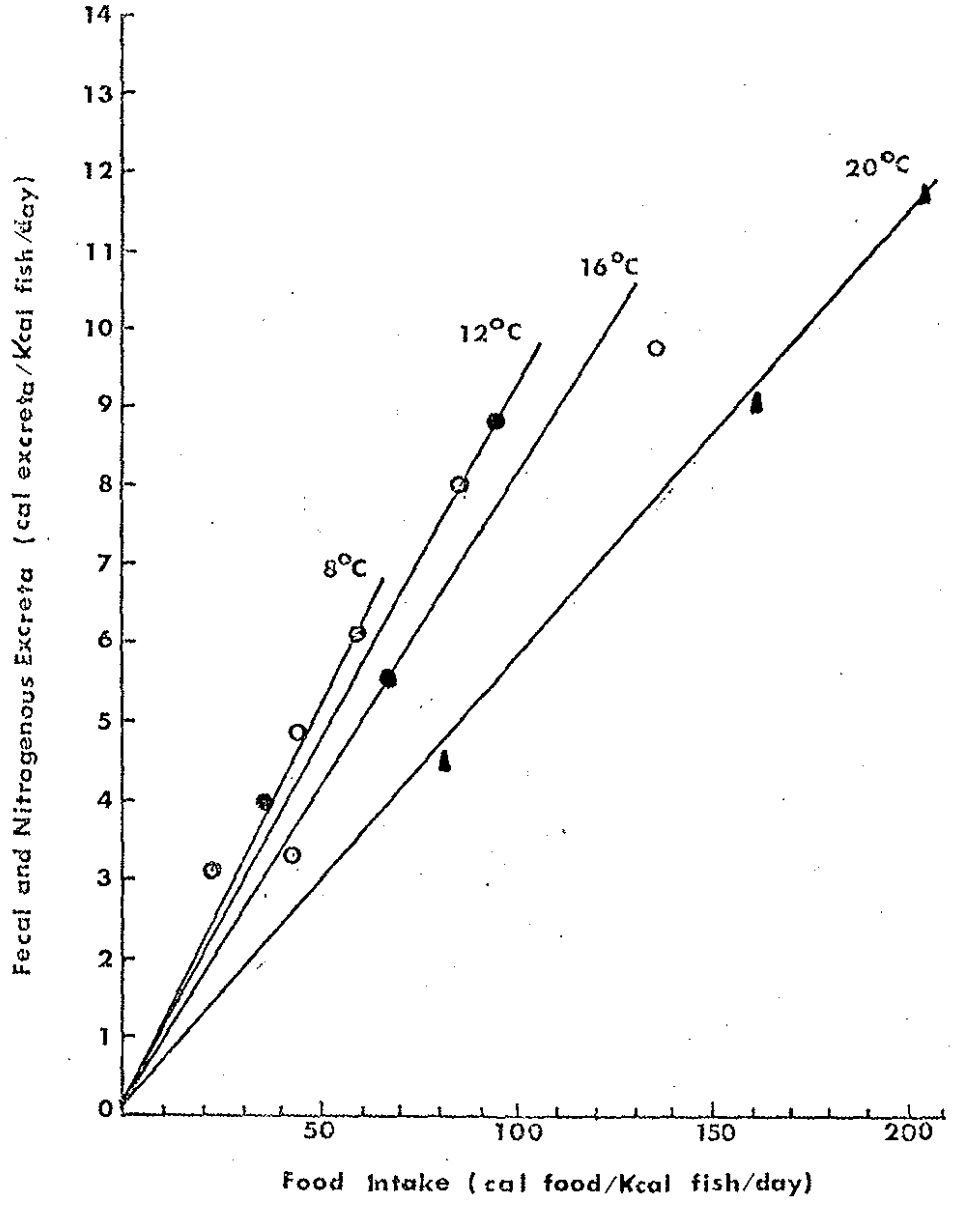

Figure 6. Fecal and nitrogenous excreta of Utah chub at various temperatures and amounts of food intake.

The metabolic rate of chub was primarily a function of food intake at the water temperature tested (Fig. 7). At any given level of food intake the metabolic rate was nearly identical for fish held at the four temperatures. Metabolic rate increased linearly as food intake was increased up to the maximum rate for each temperature.

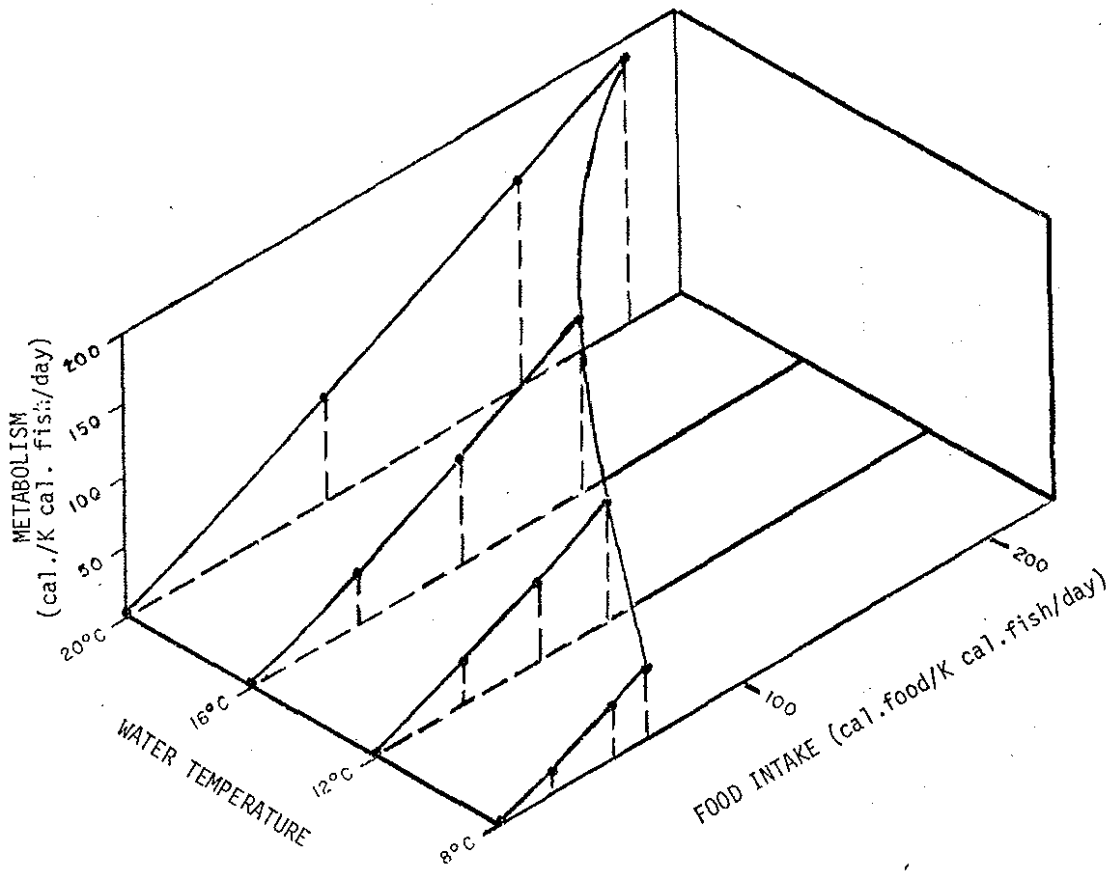

Figure 7. Metabolism of Utah chub at various temperatures and amounts of food intake.

DISCUSSION

Brown (1957) pointed out that both food intake and maintenance metabolic rate of fish were affected by temperature. The present study found that the maximum food intake of Utah chub increased as temperature increased (Table 3). The food intake required for the fish to maintain body weight (zero growth) was similar (20-30 cal/Kcal/day) at 12, 16 and 20°C, but fish were unable to maintain body weight at 8°C (Fig. 4). The metabolic rate at food intake of 20-30 cal/Kcal/day was similar at 12, 16 and 20°C (Fig. 7), indicating that the maintenance metabolism rate for chub was similar at temperatures from 12-20°C.

Growth of chub was related to both food intake and temperature. As temperature and food intake increased, absolute growth increased (Fig. 4). At a given food intake food absorption (as indicated by growth) by the chub is thought to increase as temperature increases (Figs. 4 and 5), and a smaller percentage of the food ends up as excreta (Fig. 6).

The percentage of food intake converted to growth declined as food intake increased at 12, 16 and 20°C, and increased as food intake increased at 8°C (Fig. 5). The negative slope of food intake-growth efficiency relationship has been reported previously (Paloheimo and Dickie, 1966b).

The metabolic rate calculated was the rate when fish activity was at a level intermediate to "standard and active" discussed by Beamish and Dickie (1967). Temperature had little influence on the calculated metabolic rate but food intake had a major influence. There was a three-fold increase in metabolic rate (19 to 55 cal) between fish fed the smallest or maintenance ration (22 cal food/Kcal fish/day) and largest (60 cal food) rations at 8°C, and a nine-fold increase (19-187 cal) in metabolic rate from a maintenance ration (20 cal food/Kcal fish/day) to the maximum ration fed (204 cal) at 20°C (Fig. 7 and Table 3). From the data presented by Paloheimo and Dickie (1966a), Brett (1970) pointed out the 6- to 8-fold increases in metabolic rate of fish fed a maintenance level of ration versus a maximum ration.

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