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Interactions of feeding frequency and density on food utilization in air-breathing murrel, *Channa striatus*

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Abstract. In a factorial design of experiment, effects of feeding frequency on food utilization were studied in *Channa striatus*. Feeding frequency is positively related, whereas density is negatively related to the tested energetics components; absorption efficiency remains independent of both feeding frequency and density. Based on the minimum water requirement, a fish pond with an average depth of 1·5 m and an area of 1 ha could be stocked with 1·15 million fry of *C. striatus*, of size 3 g. There is a significant interaction between feeding frequency and density suggesting that adverse effects of density could be compensated by increasing the frequency of feeding.

Keywords. Feeding frequency; density; *Channa striatus*, food utilization; air-breathing murrel.

1. Introduction

In intensive fish culture, feeding frequency and population density are two potential factors, which greatly affect growth and production. Frequent feeding has been reported to improve the growth (Kono and Nose 1971; Andrews and Page 1975; Grayton and Beamish 1977; Chua and Teng 1978). However, increasing the frequency of feeding beyond a level might lead to considerable wastage of food and increase the production cost. Secondly, total fish production can be enhanced by increasing the initial stocking density. Nevertheless, growth rate declines with increasing density (Refstie and Kittelsen 1976; Andrews *et al* 1971; Andrews 1972; Houde 1977; Trezebiatouski *et al* 1981) which will affect the final mean body weight; it is one of the considerations in consumer preference. Further, although different authors have studied feeding frequency and density separately, there is paucity of information on the interaction of feeding frequency and density. The present paper, therefore, attempts to find out the optimum feeding frequency and stocking rate as well as the interactions of feeding frequency and rearing density on food utilization in an economically important cultivable air-breathing fish *Channa striatus*.

2. Materials and methods

Channa striatus collected from ponds and lakes around Palani (Tamil Nadu, India) were acclimated to the laboratory conditions for a week. Healthy individuals (660 ± 69·1 mg) were sorted out and randomly divided into five density groups with 1, 2, 4, 8 and 16 individuals/aquarium. For brevity of expression, density groups are hitherto mentioned as 1, 2, 4, 8 and 16D groups. Each density group was subjected to five feeding frequencies. The chosen feeding frequencies and their notations are given below:

Feeding frequency (*Ff*)	Notation (*Ff*)
Twice a day	2/1
Once a day	1/1
Once in 2 days	1/2
Once in 3 days	1/3
Once in 4 days	1/4

Experiments were conducted in cylindrical aquaria (30 × 15 cm; 7 l capacity). Aquarium water was aerated throughout the experiment to maintain the PO_2 at near air-saturation. De Roth's (1967) method of aeration was suitably modified to minimise the agitation of water.

The test animals were fed *ad libitum* with freshly severed pieces of *Lepidocephalichthyes thermalis*. The food fish were brought from the market at regular intervals and maintained in the laboratory. They were fed with boiled egg daily. Care was taken to evacuate the gut before being served as food. Water and energy contents of the food (*L. thermalis*) averaged to $78 \pm 6{\cdot}7\,\%$ and $4663 \pm 67{\cdot}9$ cal/g dry weight, respectively.

Test individuals subjected to twice-a-day feeding schedule were fed at 0900 and 1900 hrs for 1 hr each and those belonging to other feeding schedules at 0900 hr for 1 hr. At the end of each feeding period, the unconsumed food pieces were collected using a pipette. Fluid loss from the food material during the feeding was estimated by keeping a control separately; it averaged to $6 \pm 0{\cdot}79\,\%$ of the ingested food, and suitable corrections were made for this loss, when the quantity of food consumed was calculated.

Faeces was collected by filtering the aquarium everyday before changing the water. To estimate the growth, a few individuals belonging to each density group or feeding frequency (controls) were sacrificed at the beginning of the experiment (Maynard and Loosli 1962) and all the individuals were killed at the end of the experiment. Dry matter and energy contents of the control individuals represent those of the test animals at the commencement of the experiment. Energy contents of food, faeces, and test animals were estimated in a Parr 1411 semi-micro bomb calorimeter. All the experiments were conducted at a temperature of 28 ± 2°C and at a photoperiod of 12–14 hr for 21 days (see also Sampath and Vivekanandan 1980).

The energetics equation followed in the present study is that of IBP formula (Petrusewicz and Macfadyen 1970) represented as

$$C = F + U + P + R,$$

where C is the food energy consumed F the energy of faeces, U the nitrogenous excretory waste, P the growth and R the energy released as heat due to metabolism.

C was estimated by subtracting the amount of unfed from the total food offered. Food energy absorbed (A) was calculated by subtracting the energy equivalent of faeces from that of C

$$A = C - F.$$

Food energy converted into body structure ($P =$ growth) was estimated as the difference between the energy contents of the individuals at the beginning and at the termination of the experiment. Energy expended on body functions ($R =$ metabolism) was calculated after subtracting the sum of energy equivalent of ammonia (U) excreted and the energy converted (P) by the fish from the energy absorbed (A).

$$R = A - (U + P).$$

For calculating the energy loss *via* ammonia, the value (1 mg ammonia = 5·9 cal) reported by Elliott (1976) was used. Absorption efficiency was calculated in percentage relating A to C. Gross conversion efficiency (K_1) was calculated relating P to C and expressed in percentage. Rates of feeding (Fr), absorption (Ar) conversion (Cr) and metabolism (Mr) were calculated relating the respective quantum of energy to the initial biomass (g) per unit time (day). The following formula was used to calculate the rates of feeding, absorption, conversion and metabolism:

$$\begin{array}{l}\text{Rate of feeding/absorption/}\\ \text{conversion/metabolism}\end{array} = \frac{\begin{array}{c}\text{Food energy consumed }(C)\text{/absorbed }(A)\text{/}\\ \text{converted }(P)\text{/metabolised }(M)\text{ (cal)}\end{array}}{\text{Initial biomass (g)} \times \text{Number of days}}$$

Efficiency of absorption and conversion were calculated using the formula

$$\begin{array}{l}\text{Efficiency of absorption/}\\ \text{Conversion (\%)}\end{array} = \frac{\text{Energy absorbed }(A)\text{/converted }(P)\text{ (cal)}}{\text{Energy consumed }(C)}$$

3. Results

Table 1 presents data on effects of feeding frequency and density on various energetics parameters in *Channa striatus* . A positive correlation exists between the frequency of feeding and feeding rate (table 2a). However, food consumption did not significantly ($P > 0{\cdot}05$) increase, when the feeding frequency was increased beyond 1/1 *Ff.* Whereas feeding rate and feeding frequency are positively correlated, density and feeding rate are inversely related (table 2a). For instance, individuals receiving food once a day (1/1) and reared in 1, 2, 4, 8 and 16 D groups consumed at the rate of 261, 248, 186, 172 and 151 cal g live fish weight^{-1} day^{-1}, respectively (table 1). Subjecting the results of feeding rate to two-way analysis of variance reveals that both feeding frequency and density as well as their interaction hold significant effect on feeding rate (table 2b).

Absorption rate follows the trends obtained for feeding rate; it is directly related to feeding frequency and inversely related to density (see table 2a). Despite a 6-fold increase in absorption rate, efficiency of absorption did not vary and it averaged to 91 % irrespective of feeding frequency and rearing density. Ponniah (1978) also arrived at the same conclusion on *Macropodus cupanus* that feeding frequency does not alter the absorption efficiency. Dawes (1930) reported that frequent feeding forces food through the alimentary canal more quickly and causes incomplete digestion. In the present study, absorption efficiency did not vary in different feeding regimes suggesting that digestion is not affected by frequent feeding and wastage of food due to incomplete digestion could be avoided in *C. striatus* culture.

Figure 1 elucidates the relationship between conversion rate and feeding frequency as well as rearing density; the rate is directly related to the frequency of feeding but

Table 1. Effects of feeding frequency and density on food utilization in *Channa striatus*.

Parameter	Density	2/1	1/1	1/2	1/3	1/4
Fr	1	207·4 ± 41·3	260·5 ± 42·4	95·6 ± 12·2	57·9 ± 4·5	40·2 ± 1·5
	2	219·5 ± 46·1	247·5 ± 0·5	98·9 ± 3·7	51·0 ± 3·3	36·0 ± 2·3
	4	233·3 ± 9·2	186·4 ± 3·5	92·5 ± 3·6	50·5 ± 3·2	34·7 ± 2·1
	8	197·1 ± 22·1	171·7 ± 12·7	83·8 ± 2·4	49·5 ± 2·1	33·8 ± 2·1
	16	173·3 ± 23·4	151·3 ± 6·3	73·8 ± 2,5	45·0 ± 1·5	30·1 ± 2·2
Ar	1	195·0 ± 51·0	233·7 ± 35·2	87·9 ± 11·1	52·5 ± 3·8	36·1 ± 1·5
	2	203·1 ± 47·0	224·0 ± 2·1	90·2 ± 3·1	46·6 ± 2·4	32·4 ± 2·2
	4	221·0 ± 9·0	170·4 ± 4·9	85·6 ± 3·1	45·9 ± 2·9	31·5 ± 1·8
	8	188·0 ± 22·0	158·4 ± 11·2	75·8 ± 2·0	42·9 ± 3·4	30·4 ± 1·9
	16	165·1 ± 22·0	140·9 ± 5·6	66·4 ± 1·8	40·5 ± 2·0	27·2 ± 2·3
Ae	1	90·4 ± 3·0	89·8 ± 0·4	92·0 ± 0·1	90·6 ± 0·6	89·7 ± 0·2
	2	94·0 ± 2·0	90·5 ± 0·7	91·2 ± 0·3	91·4 ± 1·2	89·7 ± 0·6
	4	95·1 ± 1·0	91·4 ± 0·1	92·5 ± 2·6	90·7 ± 0·3	90·8 ± 0·2
	8	95·3 ± 1·0	92·3 ± 0·4	90·6 ± 0·5	86·7 ± 0·5	90·0 ± 0·6
	16	96·2 ± 1·0	93·0 ± 0·5	90·0 ± 0·5	90·0 ± 2·4	90·2 ± 0·9
Mr	1	103·2 ± 30·8	112·0 ± 17·9	63·2 ± 8·2	43·8 ± 2·5	37·3 ± 0·3
	2	112·7 ± 26·2	110·1 ± 0·9	63·2 ± 0·5	38·9 ± 2·1	34·2 ± 0·7
	4	109·9 ± 3·6	94·3 ± 4·3	61·3 ± 1·5	38·9 ± 1·5	33·6 ± 0·7
	8	104·7 ± 4·2	79·7 ± 4·8	54·6 ± 0·2	36·6 ± 3·0	34·8 ± 1·4
	16	99·5 ± 8·2	75·3 ± 1·7	48·3 ± 0·8	35·9 ± 1·9	32·3 ± 0·9
Cr	1	76·3 ± 16·1	102·5 ± 14·4	17·5 ± 2·0	4·4 ± 1·0	−4·2 ± 1·1
	2	74·2 ± 17·4	95·5 ± 1·0	19·6 ± 2·3	3·9 ± 0·7	−4·5 ± 1·4
	4	93·5 ± 12·1	62·1 ± 8·8	17·3 ± 1·3	3·2 ± 1·1	−4·7 ± 0·9
	8	68·3 ± 16·3	65·7 ± 5·5	15·0 ± 2·0	2·8 ± 0·1	−6·9 ± 0·4
	16	52·2 ± 12·1	54·0 ± 3·4	12·7 ± 2·4	1·3 ± 0·0	−7·3 ± 1·1
K_1	1	37·2 ± 5·1	39·4 ± 12·6	18·4 ± 1·9	7·6 ± 1·3	—
	2	34·1 ± 4·0	38·6 ± 0·3	19·8 ± 1·6	7·6 ± 1·4	—
	4	40·4 ± 7·1	33·2 ± 3·7	18·7 ± 1·9	6·3 ± 2·1	—
	8	35·0 ± 7·3	38·3 ± 0·4	17·9 ± 2·1	5·6 ± 0·1	—
	16	30·1 ± 4·2	35·6 ± 2·6	17·3 ± 2·6	2·9 ± 0·0	—

Each value represents the average (± SD) performance of three replicates for each group maintained for 21 days at 28 ± 2°C. *Fr*, *Ar*, *Cr* and *Mr* refer to rates of feeding, absorption, conversion and metabolism expressed as cal g live fish^{-1} day^{-1}. *Ae* and K_1 refer to efficiency of absorption and conversion expressed in percentage.

Table 2a. Correlation coefficient between feeding rate, conversion rate and efficiency and feeding frequency and density.

Parameter	Tested factor	*r*	*df*	P
Feeding rate	Feeding frequency	+0·874	4	⩽0·05
	Density	−0·972	4	< 0·01
Conversion rate	Feeding frequency	+0·856	4	> 0·05
	Density	−0·954	4	< 0·01
Conversion efficiency	Feeding frequency	+0·991	3	< 0·01
	Density	−0·963	3	< 0·01

inversely to the density. It could be observed from the figure that the lines representing the conversion rates of individuals subjected to 1/1 and 2/1 *Ff* fall apart from those of the other feeding schedules. Moreover, the difference in the conversion rate between

Table 2b. Summary of analysis of variance for the data on feeding rate, conversion rate and efficiency.

Source	*SS*	*Df*	*MS*	*F*	*P*
		Feeding rate			
Total	459948·3	74	—	—	—
Between feeding frequencies	390955·6	4	97738·9	212·49	< 0·01
Between densities	23917·3	4	5979·3	12·99	< 0·01
Interaction	22077·5	16	137979·8	2·99	< 0·01
Residual	22997·8	50	459·9	—	—
		Conversion rate			
Total	102661·9	74	—	—	—
Between feeding frequencies	91322·6	4	22830·7	386·44	< 0·01
Between densities	2814·5	4	700·6	11·91	< 0·01
Interaction	5570·9	16	348.2	5·89	< 0·01
Residual	2953·8	50	59·08	—	—
		Conversion efficiency			
Total	10856·1	59	—	—	—
Between feeding frequencies	8977·9	3	2992·7	175·11	< 0·01
Between densities	434·2	4	108·6	6·35	< 0·01
Interaction	759·9	12	63·3	3·71	< 0·01
Residual	683·9	40	17·09	—	—

these two feeding schedules (1/1 and 2/1 *Ff*) is not statistically significant ($P > 0·05$) in all tested densities. In other words, increasing the feeding frequency from 1/1 to 2/1 may not be economical. Both feeding frequency and density as well as their interaction exert significant effect on conversion rate (table 2b).

Trends obtained for gross conversion efficiency as function of feeding frequency and density have been plotted in figure 2. Individuals subjected to 2/1 and 1/1 *Ff* clearly displayed higher conversion efficiency than those in other feeding frequencies. The maximum conversion efficiency was displayed by the individuals belonging to 1/1 *Ff* schedule in all the densities except 4 D group. Secondly individuals reared in low densities exhibited higher conversion efficiency than those in high densities. As in conversion rate, individual effect of feeding frequency and density as well as their interaction on the efficiency of conversion are significant (table 2b).

4. Discussion

The results presented here clearly reveal that feeding frequency imposes a highly significant effect on food utilization in *C. striatus*. However, absorption efficiency is independent of both frequency of feeding and density. An increase in feeding frequency, no doubt, increases food consumption and conversion; however, there is a limit to increase in feeding. Also there is a clear segregation of conversion rate and efficiency between the lower and higher feeding frequencies (figures 1 and 2). These parameters remarkably dropped, when the frequency was reduced from 1/1 to 1/2 *Ff*. On the other hand, increase in feeding frequency from 1/1 to 2/1 *Ff* did not show any appreciable improvement in the performance; in fact, in low densities, they fed and converted less than those belonging to 1/1 *Ff* schedule. Further, individuals in the once-a-day feeding

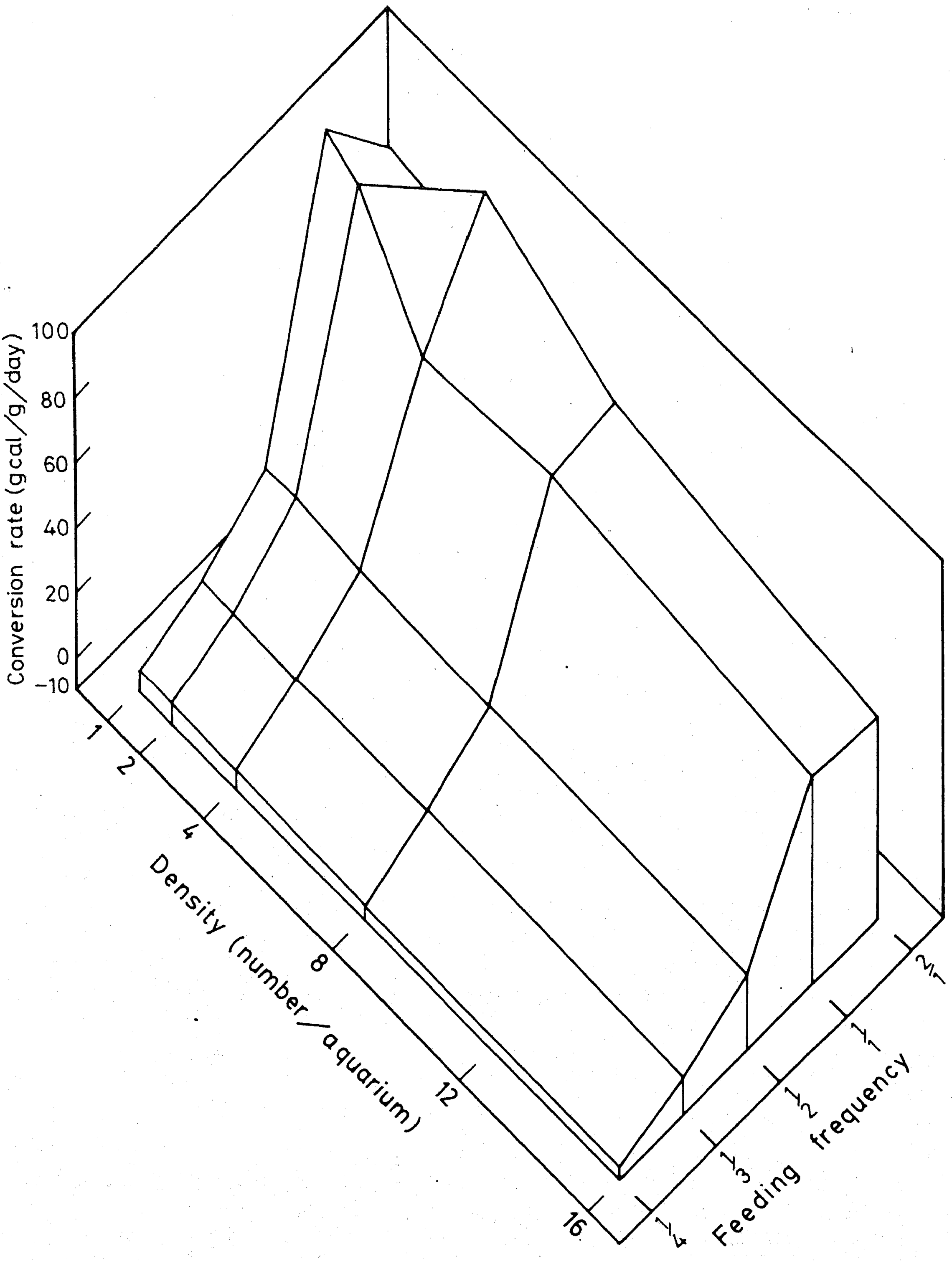

Figure 1. Effects of feeding frequency and density on the conversion rate of *Channa striatus.*

frequency (1/1) show the highest conversion efficiency (figure 2). Therefore, 1/1 schedule is considered optimum for *C. striatus*. However, earlier reports indicate a wide variation in the optimum feeding frequency. Andrews and Page (1975) obtained the highest food efficiency in the channel catfish *Ictalurus punctatus* at a feeding frequency

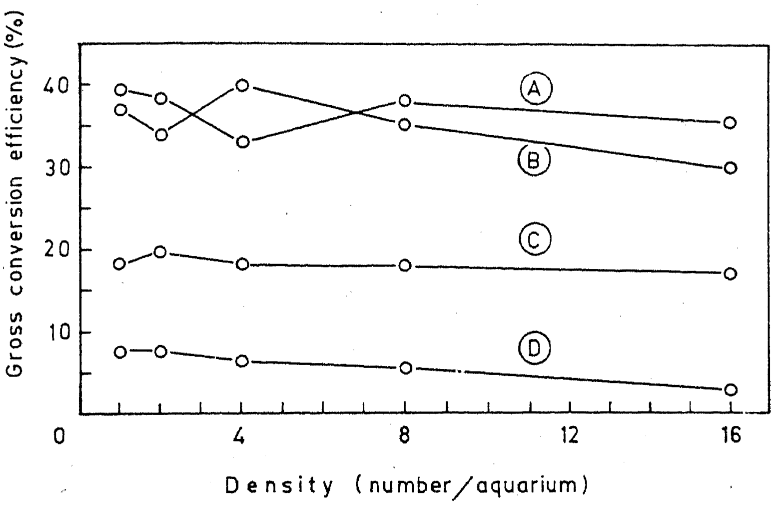

Figure 2. Gross conversion efficiency as function of feeding frequency and density in *Channa striatus.* A, B, C and D represent *Ff* of 2/1, 1/1, 1/2 and 1/3 respectively.

of 2/1 (see also Crayton and Beamish 1977). Chua and Teng (1978) found 1/2 *Ff* as the optimum frequency for the group *Epinephelus tauvina.* Ponniah (1978) recommends 1/1, 2/1 and 3/1 *Ff* as optimum for 0·7, 0·5 and 0·1 g *M. cupanus.* It is likely that discrepancy in the optimum feeding frequency is due to species and size differences.

Food intake is governed by the development of appetite, which, in turn, depends on the amount of food remaining in the stomach (Brett 1971; Pandian 1975). The highest food consumption observed in 1/1 *Ff* schedule suggests that maximum appetite is reached in *C. striatus* between 12 and 24 hr of meal. Nevertheless, extension of food deprivation time beyond 24 hr not only reduced the food consumption to less than 50% but also the conversion of consumed food; the rate and efficiency of conversion were also reduced by more than 50%.

Contrary to the effects of feeding frequency, all the parameters of food utilization decrease with increasing density. Analysis of variance shows that difference in the rates of feeding, conversion, and efficiency of conversion were statistically significant (table 2b). The adverse effects of density may be attributed to the following causative factors: (i) development of size hierarchy, (ii) accumulation of metabolism in the medium and (iii) availability of food; Magnification of size disparity among the individuals of culture species, as the culture progresses seriously affects the growth rate of the population. Sampath and Pandian (1983) found that presence of a few fast growing individuals of *C. striatus* retarded the growth of smaller individuals by preventing them from feeding. Secondly, there are evidences to show that accumulation of metabolites in the medium contributes to the harmful effects of crowding in fish (Kawamoto 1961; Groves and Kogel 1973). Among the several metabolites, ammonia produces serious ill effects. Accumulation of ammonia affects growth through several mechanisms such as reduction of appetite, damage of gills and switching over to urea excretion. Thirdly, shortage of food in high density has been shown to limit growth (Brocksen 1966). Not only shortage of food but also under *ad libitum* conditions in the laboratory, food consumption decreases in high densities due to competitive interactions among the individuals (Houde 1975).

Although rates of feeding and conversion decline with increase in density, in the optimum feeding frequency (1/1 *Ff*), the decrease in conversion rate becomes statistically significant, when increased beyond 2 individuals/aquarium ($t = 5{\cdot}34$; $df = 4$; $P < 0{\cdot}01$). Therefore, culturing 2 individuals/7 l of water will be profitable. Considering the mid biomass (2·66 g) in 2 D group, it is evident that a minimum of 2·6 l of water is required for 1 g of *C. striatus*. Based on this water requirement, it has been calculated that a fish pond with an average depth of 1.5 m (Ling 1977) and an area of 1 ha could be stocked with 1,153,846 fry of *C. striatus* or 577 kg of biomass at the size of 3 g.

Among the two variables tested, the feeding frequency is the dominant factor. It accounts about 90% of the total variation. Further, there is a significant interaction between feeding frequency and density on the rates of feeding and conversion and efficiency of conversion. As already stated the food intake and conversion decrease with increasing density. However, the magnitude of decrease is less pronounced in higher feeding frequencies than in lower feeding frequencies. In other words, the adverse effects of density could be compensated by increasing the frequency of feeding.

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