



Spontaneous activity was unaffected by ration size in Nile tilapia and gibel carp

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Two growth trials using a range of ration sizes from starvation to maximum feeding suggested that linear relationships existed between specific growth rate and ration size for Nile tilapia and gibel carp. Continuous measurement of activity showed that activity level, in terms of distance swum per day, was not affected significantly by ration size in both Nile tilapia and gibel carp.

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Bioenergetics models have been used widely in fishery management to predict growth and food consumption by fish populations (Kitchell *et al.*, 1977; Hewett & Johnson, 1992; Railsback *et al.*, 1999). The model is based on the energy budget equation: $G = C - F - U - R_s - SDA - R_a$, where G is growth, C is food consumption, F and U are energy lost in faeces and excreta respectively, R_s is standard metabolism, SDA is specific dynamic action and R_a is activity metabolism (Brett & Groves, 1979). In most models, R_a is regarded as a fixed multiple of standard metabolism (Kitchell *et al.*, 1977; Hewett & Johnson, 1992). The underlying assumption is that activity cost in fish is independent of ration size. Such an assumption, however, remains untested. Cui & Wootton (1989) suggested that one of the reasons for the failure of their bioenergetics model to predict the growth of the minnow *Phoxinus phoxinus* (L.), may be inaccurate prediction of activity metabolism.

Only two studies reported direct measurements of the relationship between activity and ration in fish under laboratory conditions (Vivekanandan, 1976; Wurtsbaugh & Cech, 1983). However, both studies used rather crude methods to quantify activity. There is a need to establish the activity-ration relationship in fish, based on accurate quantification of spontaneous activity.

In a previous study, Qian *et al.* (2000) found that there was no significant effect of previous food deprivation on the activity of gibel carp *Carassius auratus gibelio* (L.) during compensatory growth. The purpose of the present study was to test the hypothesis that spontaneous activity was unaffected by ration size for Nile tilapia *Oreochromis niloticus* L. and gibel carp.

Gibel carp and Nile tilapia were obtained from hatcheries in Wuhan. Forty to 50 fish were transferred into a holding tank (70 × 50 × 60 cm; water depth 40–50 cm) in a constant temperature room 2 weeks prior to the experiments. Water temperature was adjusted gradually to 25°C (1–2°C day⁻¹) and the fish were acclimatized at this temperature for 1 week. Fluorescent lights (105 lx) were used between 0800–2000 hours, and red lights (0.5 lx) used from 2000–0800 hours. During this acclimatization period,

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the fish were fed to satiation twice a day at 0900 and 1600 hours on the experimental dry pellet diet (protein content 38%) as described in Qian *et al.* (2000). Yttrium oxide (Y_2O_3) was incorporated in the diet at 0.1% as inert marker for digestibility measurements.

Four ration levels were tested in the experiment for each species. They were starvation, 2 and 4% of body weight per day and satiation twice a day for Nile tilapia, and starvation, 1.5 and 3.0% of body weight per day and satiation twice a day for gibel carp. Following 2 days of food deprivation, 16 fish (initial weight: 1.94–2.08 g for Nile tilapia and 2.97–3.18 g for gibel carp) were weighed individually and distributed at random among the 16 plexiglas tanks (40 × 20 × 20 cm; water 10–12 cm deep). Four tanks were assigned to each ration level. At each feeding, a weighed quantity of food was fed to each tank at 0900 and 1600 hours. For fish fed satiation ration, uneaten food was collected 1 h later by siphoning, dried at 70° C and weighed, correcting for weight loss in the uneaten feed (Qian *et al.*, 2000). All the food was consumed by fish fed the restricted rations. Faeces were collected for digestibility analysis by siphoning twice a day, faeces that remained intact being dried at 70° C and then frozen at –20° C until analysed. Activity was monitored using the system described in Qian *et al.* (2000) on 4 days for each tank. Activity was recorded by an activity monitoring system (Videomex V, Columbus Corporation, Ohio, U.S.A.) through a videocamera mounted above the tanks. Horizontal distance swum per unit time and per cent time moving were monitored continuously. Each day, four tanks, each from one ration, were monitored. Activity measurement was recorded from 0900 to 2000 and 2100–0800 hours and the camera was moved to record another four fish the next day. One period terminated when activity for the 16 fish was completely recorded and activity was monitored for four periods during the experiment. One third of the water in each tank was replenished twice a day. Weekly measurements of water quality showed that dissolved oxygen ranged from 6.5 to 8.8 mg l⁻¹, pH from 6.7 to 8.1 and NH₄-N < 0.5 mg l⁻¹.

At the end of the 24 day experiment, fish were weighed individually following 2 days deprivation. Contents of protein, energy and Y_2O_3 of the diet and faecal samples from each tank were analysed, in duplicate, as described in Qian *et al.* (2000). Specific growth rate (G) and growth efficiency were calculated as described by Qian *et al.* (2000). Ration size was food consumed per unit body weight per day. Apparent digestibilities of dry matter, protein and energy were estimated using Y_2O_3 as marker.

Two models were used to fit the growth (G)-ration (R) relationship, using least-squares regression, $G = a + bR$ and $G = a + b \ln(R + 1)$. Analysis of variance (ANOVA) was used to analyse the differences in growth efficiency and apparent digestibility among groups. Duncan's multiple range test was used for multiple comparisons. Repeated measures ANOVA was used to analyse the effect of ration and measuring period on activity. Each 4-day period, in which all individuals were monitored once, was regarded as one period. Planned comparisons were used to compare the difference among ration groups in each period or between periods for each ration. Differences were regarded significant when $P < 0.05$.

Both the linear and curvilinear models, when fitted to the growth-ration relationship in the two species, had a high r^2 and the residual analyses did not reveal systematic patterns. The linear model was chosen for both species because of its slightly higher r^2 and simplicity (Fig. 1). Growth efficiency was not significantly affected by ration in Nile tilapia, but increased when fish were fed a higher ration in gibel carp (Table I). No significant differences were found in digestibilities among rations in both species except that dry matter digestibility in tilapia was significantly lower at 2% than at higher rations (Table I).

Repeated measures ANOVA showed that in neither species was the distance swum per day significantly affected by ration size ($F_{3,12} = 0.655$, $P = 0.595$ for Nile tilapia; $F_{3,12} = 1.221$, $P = 0.344$ for gibel carp), period ($F_{3,36} = 2.663$, $P = 0.626$ for Nile tilapia; $F_{3,36} = 0.581$, $P = 0.631$ for gibel carp) or their interaction ($F_{9,36} = 0.345$, $P = 0.953$ for Nile tilapia; $F_{9,36} = 0.410$, $P = 0.922$ for gibel carp) (Fig. 2).

In Nile tilapia, time spent swimming was affected significantly by period ($F_{3,36} = 3.250$, $P = 0.033$), but not by ration ($F_{3,12} = 2.724$, $P = 0.0908$) or the ration-period interaction ($F_{9,36} = 0.631$, $P = 0.763$). Planned comparisons showed that starved tilapia spent

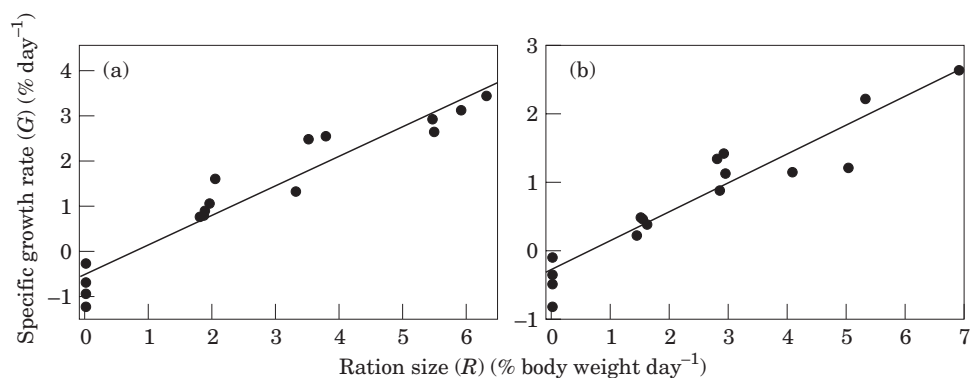


FIG. 1. Relationships between specific growth rate (G) and ration size (R) for Nile tilapia (a) and gibel carp (b). (a) $G = -0.49 + 0.65R$; $r^2 = 0.93$; (b) $G = -0.24 + 0.42R$; $r^2 = 0.91$.

TABLE I. Effect of ration size on growth efficiency and apparent digestibilities of dry matter, protein and energy in Nile tilapia and gibel carp (means \pm s.e.¹)

Species	Ration (%)	Growth efficiency (%)	Apparent digestibility (%)		
			Dry matter	Protein	Energy
Nile tilapia	2	65.1 \pm 11.4	65.9 \pm 1.5a	90.6 \pm 0.8	87.7 \pm 0.5
	4	70.8 \pm 12.9	71.3 \pm 0.9b	92.4 \pm 0.9	89.0 \pm 0.5
	Satiation	78.9 \pm 3.4	72.7 \pm 0.6b	92.6 \pm 0.2	88.5 \pm 0.6
Gibel carp	1.5	29.7 \pm 2.0a	66.3 \pm 3.2	92.2 \pm 0.9	82.2 \pm 1.8
	3	46.4 \pm 5.3b	70.2 \pm 2.7	92.0 \pm 0.7	84.7 \pm 1.8
	Satiation	50.6 \pm 0.7b	73.3 \pm 1.8	91.4 \pm 1.8	84.5 \pm 2.0

¹Letters after each value indicate results of multiple range test (Duncan's procedure); means with different letters were significantly different from each other ($P < 0.05$).

significantly less time swimming in the second period than in the other periods, and tilapia fed 2% ration spent more time swimming in the fourth period than in other periods (Fig. 2). In gibel carp, time spent swimming was affected marginally significantly by ration ($F_{3,12} = 3.33$, $P = 0.056$), but not by period ($F_{3,36} = 0.452$, $P = 0.718$) or the ration-period interaction ($F_{9,36} = 1.104$, $P = 0.385$). Planned comparisons showed that during the second period, starved gibel carp spent less time swimming than those fed 3% and maximum rations, and during the fourth period, gibel carp fed the 3% ration spent more time swimming than those fed 0 and 1.5% rations (Fig. 2).

The results suggested that activity level, expressed as total distance swum per day, was not affected by ration size. Time spent swimming was affected marginally by ration in gibel carp, but such effects did not seem to follow a regular pattern. Distance swum is probably more important than time spent swimming in determining the energy cost of activity, and the results in general supported the hypothesis that activity level was not affected by ration size. This conclusion was somewhat inconsistent with results from several previous studies. Kerr (1982) proposed a linear relationship between activity metabolism and ration size in actively predatory fishes. However, the relationship was derived indirectly from the growth efficiency data in cod *Gadus morhua* L. (Edwards *et al.*, 1972). By using bioenergetics models to fit the field estimates of growth and food consumption data for *Perca flavescens* Mitchell, Boisclair & Leggett (1989) also suggested

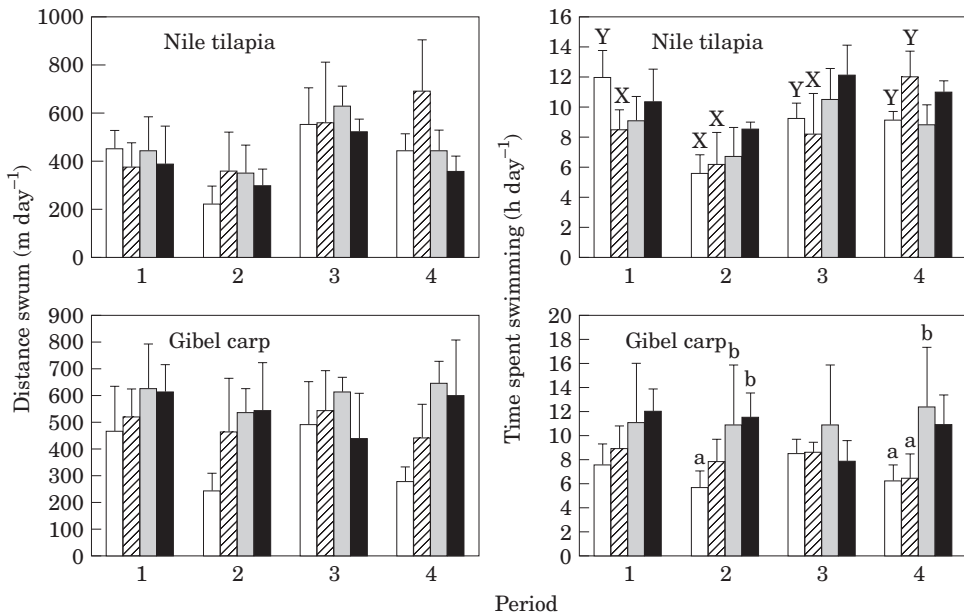


FIG. 2. Effect of ration size on swimming activity for Nile tilapia and gibel carp. Errors bars represent 1 s.e. Different lower case letters (a, b) indicate significant differences (planned comparisons) between ration groups in the same period. Different upper case letters (X, Y) indicate significant differences between periods for the same ration group. Nile tilapia: □, 0; ▨, 1-5; ▩, 3; ■, satiation. Gibel carp: □, 0; ▨, 1-5; ▩, 3; ■, satiation.

that activity cost increased with ration size, but their work does not constitute a true test of the activity-ration relationship because activity estimates were derived by modelling, using feeding and growth data. Boisclair (1992) measured activity directly and food consumption during six 1-h periods of a day for brook trout *Salvelinus fontinalis* Mitchell in an enclosure using the stereocinematographic method, and found a positive relationship between activity and food consumption. However, the relationship was established based on measurements of activity and food consumption over a diel cycle. Swimming activity was reported to be highest at intermediate ration sizes in mosquitofish *Gambusia affinis* (Baird & Girard) (Wurtsbaugh & Cech, 1983), and increase with ration in an obligatory air-breathing fish, *Ophiocephalus striatus* Bloch (Vivekanandan, 1976). In these two studies, the activity was measured using rather crude measures, i.e. number of crossings through a square or visual estimates of swimming speed within 1 min per day in Wurtsbaugh & Cech (1983), and visual estimates during two 30-min periods in Vivekanandan (1976). Such estimates cannot be regarded as representative of daily activity. The air-breathing nature of *O. striatus* complicated the situation further as the increase in respiration requirement with ration is expected to result in increases in surfacing activity. The findings of the present study were for laboratory conditions in which fish have easy access to food at fixed times of the day, and may not be applicable to natural situations, especially for fishes that need to forage actively for food. Future studies should investigate the activity-ration relationship in fishes with different feeding behaviour.

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