

ELAYAPERUMAL VIVEKANANDAN, PALANISAMY EASWARI
THAVAMANI J. PANDIANEFFECTS OF FOOD QUALITY ON SWIMMING ACTIVITY AND FOOD
UTILIZATION IN THE AIR-BREATHING FISH
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ABSTRACT

In cylindrical aquaria, liver-fed *O. striatus* increased surfacing from 1104 times at 2.5 cm depth to 1738 times/day at 40 cm depth. Due to the sustained surfacing, *O. striatus* "hung" to the surface 20 times for 1 h/day in the former and 27 times for 3.2 h/day in the latter. Feeding increased from 24 to 40 mg/g·day, assimilation 21 to 34 mg/g·day and metabolism 0.5 to 1.1 ml O₂ uptake/g·h in these groups. Since the former surfaced travelling 53 m/day, its production rate (7.3 mg/g·day) and efficiency (35%) were higher than those (6.0 mg/g·day; 17%) at 40 cm depth, which swam 1206 m/day. Comparison of the data with those of muscle-fed *O. striatus* revealed that feed quality changed food utilization, but not swimming activity.

1. INTRODUCTION

Since standard metabolism relates to "maintenance energy cost" of nonfeeding, nondigesting, nongrowing, nonactive fish, Winberg (1956) rightly appealed for more studies on active metabolism (see also Klekowski 1970). Feeding-rate and conversion efficiency estimates are considered better parameters for assessing metabolic rates and efficiencies (Kinne 1960), as they provide 1. the less restricted maintenance conditions during feeding experiments, 2. the possibility of repeatedly observing one and the same individual over a long period of time, 3. the possibility of measuring the effects of quality and quantity of food on metabolism (Pal oheim, Dickie 1966a, b) and 4. the possibility of measuring the total metabolism including the energy expended on part or total anaerobiosis (Kutty 1968, 1972; Blažka 1958, however see also Brett 1973).

For studying active metabolism, as determined by feeding rate and conversion efficiency estimates, we have chosen *Ophiocephalus striatus*, an obligatory air-breathing tropical fish (Johansen 1970). By rearing the fish in cylindrical aquaria containing different depths of water, the fish were forced to swim longer or shorter distance per unit time for exchanging atmospheric air. For instance, in aquarium containing the maximum (40 cm) water depth offered, the (feeding) fish surfaced once in 46 ± 9.6 (SD) sec; the to and fro swimming activity required a total period of 10 ± 3.2 (SD) sec to cover the distance of about 80 cm. Except for the regular interval of about 36 sec resting at the bottom, the fish was observed to exhibit a maximum sustained swimming activity, i.e. in effect, it was more or less continuously and actively swimming, as if kept in Fry's or Brett's respirometer; in addition to this, the design of the experiment permitted long term feeding and growth studies.

Environmental factors like water depth, food ration and temperature significantly changed both swimming activity and food utilization in the air-breathing fishes like *O. striatus* and *Heteropneustes fossilis* (Pandian, Vivekanandan 1976, Vivekanandan 1976, Vivekanandan, Pandian in prep., Arunachalam et al. 1976); however, Pandian et al. (1976) showed that the factors like the partial oxygen pressure (P_{O₂}) altered the swimming activity but not the rate and efficiency of food utilization in the obligatory air-breathing fish *Anabas scandens*. As an extension of these publications, the present experiment was carried out in *O. striatus* to study whether food quality modifies swimming activity and food utilization pattern or any one of them.

2. MATERIAL AND METHODS

The experimental design followed in the present study has been described in detail elsewhere (Pandian, Vivekanandan 1976). Briefly, reared in cylindrical aquaria (5 cm diameter) containing different depths of water (2.5, 5.0, 15.5, 31.0 and 40.0 cm), *O. striatus* (1.1 ± 0.1 g; 4.8 ± 0.8 cm body length) swam longer or shorter distance to exchange atmospheric air. The test individuals were fed on energy rich goat-liver (containing about 5400 g cal/g dry weight), twice a day for a period of 1 hr each. The results are compared with those reported by Pandian, Vivekanandan (1976) for *O. striatus* (0.75 g) fed on muscle of *Tilapia mossambica* containing about 4530 g cal/g dry weight, i.e. per unit weight of food consumption, the liver-fed series received nearly 20% more energy than the muscle-fed series.

Faeces were collected by filtering the entire aquaria once in 3 days. "Sacrifice Method" (Maynard, Loosli 1962) was used for determining the water content of the test individuals before commencement of experiment. The experiment was conducted in a laboratory where — except for feeding and observation — there was no disturbance. Number of surfacing by each test individual was observed for a known period of time (20 to 30 min), 3 times a day at 7 a.m., 1 p.m. and 7 p.m. The distance travelled per individual per day was estimated by multiplying the mean number of visits per unit observation time with twice the depth of water.

3. RESULTS AND DISCUSSION

O. striatus fed on goat-liver steadily increased the number of surfacing from 1104 at 2.5 cm water depth to 1738 times/day at the maximum depth of 40 cm (Tab. I). After every few surfacing, the fish resorted to a behavioural adaptation of "hanging" to the surface for a definite period of time; in addition to the branchial respiration, "hanging" to the surface permitted the obligatory air-breathing *O. striatus* to exchange gas without undertaking vertical movement (see also Pandian, Vivekanandan 1976). "Hanging" frequency increased from 20 times/day in aquaria containing 2.5 and 5 cm depth of water to about 32 times/day for the groups exposed to 15.5 cm water depth. Since the duration per "hanging" varied in the tested groups, total duration of "hanging" increased from about 1 h/day in the former groups to 2.5 and 3.2 h/day in the groups exposed to 31 and 40 cm water depths. Using the respective "hanging" duration value, the mean number of surfacing arrived from the routine observations was corrected; from corrected surfacing value, the actual distance swam by each test group to exchange atmospheric air was calculated. The distance travelled by the fish progressively increased from about 53 m/day in the group exposed to the minimum depth to 1206 m/day in that at 40 cm depth (Tab. I). The corresponding groups of *O. striatus* fed on *Tilapia* muscle (Pandian, Vivekanandan, 1976) are reported to surface more or less equal number of times and to travel equal distance/day, though they "hung" to the surface for more than 3 hours in aquaria containing less than 15.5 cm water depth (Tab. II). The minor differences observed in the number of surfacing and distance travelled between the respective groups in the liver and muscle-fed series were not statistically significant (Student's "t" test; $P < 0.10$). Therefore, change in the food quality from the energy-rich liver to the low energy containing muscle did not appreciably influence the surfacing and swimming activities of *O. striatus*.

The results (Tab. I and II) show that the muscle-fed *O. striatus* consumed 33% more food (32 mg dry muscle/g live fish. day) than the liver-fed fish (24 mg/g.day) in aquaria containing 2.5 cm depth. This initial 33% difference decreased to about 25% as the food consumption of the muscle and liver-fed series at 40 cm depth

Table I. Effects of different depths of water on swimming activity and food utilization in *Ophiocephalus striatus*. Each value represents the average performance of 3 individuals (mean \pm SD) fed on goat-liver for 21 days at 27°C

Parameters	Depth of water (cm)				
	2.5	5.0	15.5	31.0	40.0
Number of surfacing/day	1104 \pm 43.7	1236 \pm 47.1	1453 \pm 71.5	1738 \pm 82.4	1738 \pm 84.6
"Hanging" frequency (times/day)	20 \pm 0.5	20 \pm 1.4	32 \pm 1.5	31.3 \pm 3.3	27 \pm 1.1
"Hanging" duration (h/day)	1.0 \pm 0.11	1.0 \pm 0.14	2.0 \pm 0.19	2.5 \pm 0.19	3.2 \pm 0.34
Distance travelled (m/day)	52.9 \pm 2.18	118.5 \pm 4.70	412.8 \pm 22.15	968.7 \pm 57.07	1205.6 \pm 67.60
Consumption of food (<i>C</i>) (mg/g·day)	24.2 \pm 2.15	25.3 \pm 0.50	27.3 \pm 8.71	34.6 \pm 0.77	39.7 \pm 0.80
Assimilation (<i>A</i>) (mg/g·day)	20.9 \pm 1.36	21.2 \pm 0.68	23.2 \pm 4.53	29.3 \pm 0.97	34.1 \pm 0.40
Production (<i>P</i>) (mg/g·day)	7.3 \pm 0.94	6.4 \pm 0.20	6.0 \pm 1.22	6.0 \pm 0.41	6.0 \pm 0.25
Metabolism (<i>M</i>) (mg/g·day)	13.5 \pm 1.08	14.8 \pm 0.55	17.2 \pm 1.09	23.3 \pm 1.03	28.1 \pm 0.18
„ „ (ml O ₂ /g·h)	0.5 \pm 0.06	0.6 \pm 0.02	0.7 \pm 0.13	0.9 \pm 0.04	1.1 \pm 0.01
Assimilation efficiency (<i>A/C</i>) (%)	86.0	98.4	84.9	84.6	85.8
Net production efficiency ($K_2 = P/A$) (%)	35.1	30.3	25.8	20.7	17.5
Gross production efficiency ($K_1 = P/C$) (%)	30.2	25.4	21.9	17.5	15.3

Table II. Effects of different depths of water on swimming activity and food utilization in *Ophiocephalus striatus*. Each value represents the average performance of 3 to 6 individuals (mean \pm SD) fed on *Tilapia mossambica* muscle for 21 days at 27°C (Data of Pandian, Vivekanandan, 1976)

Parameters	Depth of water (cm)				
	2.5	5.0	15.5	31.0	40.0
Number of surfacing/day	1294 \pm 105.6	1317 \pm 158.4	1510 \pm 144.0	1798 \pm 122.4	1879 \pm 146.4
"Hanging" duration (h/day)	7.4 \pm 1.09	3.2 \pm 0.67	3.0 \pm 0.84	2.5 \pm 0.59	3.0 \pm 1.00
Distance travelled (m/day)	44.7 \pm 5.04	114.2 \pm 15.38	408.7 \pm 43.11	999.3 \pm 74.00	1317.9 \pm 112.20
Consumption of food (C) (mg/g. day)	32.0 \pm 4.21	35.4 \pm 1.47	43.2 \pm 4.13	47.8 \pm 1.36	49.1 \pm 3.50
Assimilation (A) (mg/g·day)	27.1 \pm 4.21	29.8 \pm 1.71	34.8 \pm 6.41	39.9 \pm 1.62	41.3 \pm 2.90
Production (P) (mg/g·day)	6.7 \pm 0.52	7.0 \pm 0.27	6.2 \pm 0.21	5.6 \pm 0.22	5.5 \pm 0.50
Metabolism (M) (mg/g·day)	20.4 \pm 3.69	22.8 \pm 1.44	28.6 \pm 6.20	34.3 \pm 1.40	35.8 \pm 2.40
„ „ (ml O ₂ /g·h)	0.8 \pm 0.14	0.9 \pm 0.06	1.1 \pm 0.24	1.3 \pm 0.06	1.4 \pm 0.09
Assimilation efficiency (A/C) (%)	85.1	84.0	80.5	83.6	83.9
Net production efficiency (K ₂ = P/A) (%)	24.0	23.5	18.0	14.0	13.3
Gross production efficiency (K ₁ = P/C) (%)	20.9	19.8	14.4	11.7	11.2

were 49 and 40 mg/g·day, respectively (Fig. 1). It may be recalled that the goat-liver is known to contain about 20% more energy per unit weight than *Tilapia* muscle. The fact that the fish consumed rations ranging from 24 to 49 mg/g·day indicates that *O. striatus* increased its stomach capacity to 2 times (cf. Brett 1971), depending on the energy required for surfacing and swimming activities in aquaria

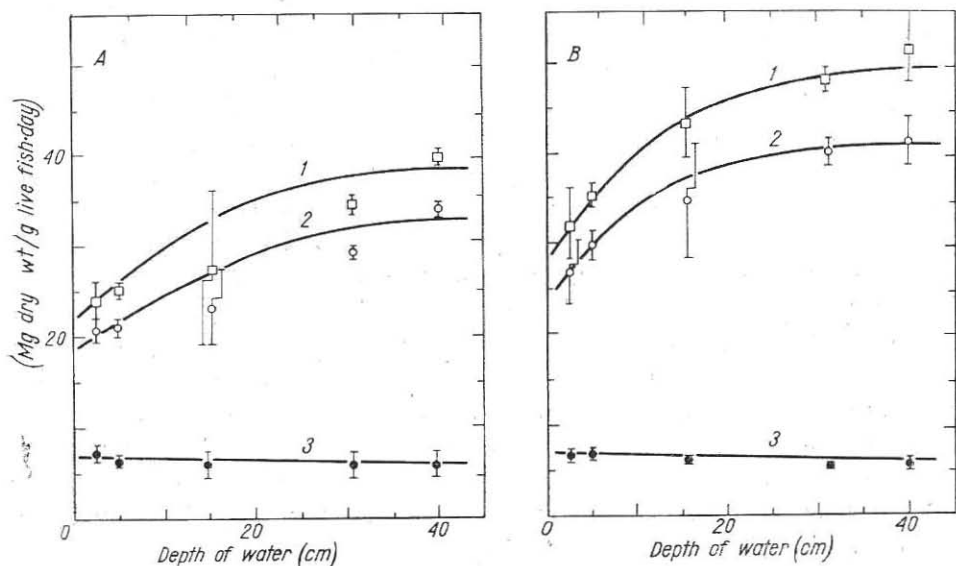


Fig. 1. Effects of depth of water on feeding (1), assimilation (2) and production (3) in young *Ophiocephalus striatus* fed on goat-liver at 27°C (given in panel A). For comparison, data reported by Pandian, Vivekanandan (1976) for *O. striatus* fed on *Tilapia* muscle are given in panel B. The vertical lines indicate SD.

containing different depths and energy available per unit weight in the consumed food like liver and muscle, and that *O. striatus* fed to satisfy its energy demand rather than to fill its stomach to the maximum capacity (Rozin, Mayr 1961, see also Pandian 1975).

Food assimilation efficiency averaged 85.1% in the liver-fed series, and it did not appreciably vary among the different groups, despite the fact that there was 66% increase in the food consumption of the group at 40 cm depth (see also Gerking 1955, 1971, Pandian 1967a, b, Vivekanandan 1976); hence the trend obtained for assimilation rate as function of depth of water is almost parallel to the one obtained for feeding rate against depth of water (Fig. 1A). In the muscle-fed series also, Pandian, Vivekanandan (1976) reported similar results (Fig. 1B)

In both the tested series, maximum production and production efficiency (K_2) were exhibited in the groups exposed to 2.5 cm water depth (7.3 mg/g·day and 35.1% in the liver-fed series; 6.7 mg/g·day and 24% in the muscle-fed series), and minimum in those exposed to the maximum water depth (6.0 mg/g·day and 17.5% in the liver-fed series; 5.5 mg/g·day and 13.3% in the muscle-fed series). At any corresponding depth, the liver-fed series converted the food nearly $1\frac{1}{2}$ times more

efficiently than those fed on muscle. *Heteropneustes fossilis*, fed on goat-liver, also exhibited such high production efficiency (44.4%) at 20 cm water depth (Arunachalam et al. 1976). Mammalian liver appears to contain growth promoting substances (Cortland Hatchery Reports 1952). On the whole, the change in food quality from *Tilapia* muscle to goat-liver considerably influenced the food consumption and production efficiency.

Metabolism of *O. striatus* was determined subtracting dry weight equivalent of production from that of assimilation; the energy value of the fish was estimated to be 4594 ± 91.1 (SD) g cal/g dry weight, and this value was converted into oxygen equivalent, using the oxy-calorific value of 4.8 cal = 1 ml of oxygen uptake (Engelmann 1966). Metabolism of *O. striatus* in aquaria containing 40 cm water depth were 1.1 and 1.4 ml $O_2/g \cdot h$ in the liver and muscle-fed series, respectively. These values are approximately 2 times higher than that (0.63 ml $O_2/g \cdot h$) reported for the sustained active metabolism of *Oncorhynchus nerka* (Brett 1964), which is already known to be one of the highest values available in the literature. However, the average weight of *O. striatus* used in both the series was only 1 g and *O. nerka* used by Brett weighed 50 g. It is well known that with increasing body weight metabolism (ml $O_2/g \cdot hr$) decreases (Zeuthen 1947, Pandian 1967a). A 40 g weighing *O. striatus*, whose metabolism was estimated using the procedure described in this paper has been found to consume 0.7 ml $O_2/g \cdot h$ (Vivekanandan, unpublished); this value favourably compares with that (0.63 ml $O_2/g \cdot h$) for the 50 g weighing *O. nerka*. For further details, consult Pandian, Vivekanandan (1976), and Arunachalam et al. (1976).

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