

FOOD INTAKE, CONVERSION AND SWIMMING ACTIVITY IN THE AIR-BREATHING CATFISH *HETEROPNEUSTES FOSSILIS*

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Introduction

Pandian & Vivekanandan (1976) and Vivekanandan (1976), who considered feeding rate and conversion efficiency estimates as parameters for assessing metabolic rates and efficiencies, observed that the obligatory air-breathing fish *Ophiocephalus striatus*, reared in aquaria containing different depths of water, swam longer or shorter distance to exchange atmospheric air; such a design of experiment permitted them to measure food intake, growth and sustained active metabolism on a long term basis. They found that the fish in deeper waters consumed significantly more food and swam longer distance dissipating more energy on metabolism and swimming activity. As an extension of these studies, this preliminary experiment was carried out in another air-breathing fish *Heteropneustes fossilis*.

Material and methods

Healthy individuals of *H. fossilis* (20 ± 3.8 g; 17 cm) were acclimatized to laboratory conditions and feeding schedules in the respective aquaria. For the experiments, cylindrical (20 cm diameter) aquaria (capacity: 15 l) were chosen to minimize swimming activity in horizontal direction. Three test series of individuals were exposed to 20, 40 and 60 cm water depths (respective water volumes: 6, 12 and 18 l); they travelled about 2, 5 or 7 times their total body length when they returned to the maximum depth available after each surfacing.

Each series comprised 2 groups; one was starved and the other was offered excess food twice a day, for a period of 2 hr each; pieces of goat liver were used as food. Care was taken to collect unfed liver with a pipette causing least disturbance to the fish, and suitable corrections were made for fluids lost by the liver pieces during 2 hour feeding period. Faeces were collected by filtering the entire aquaria once in 3 days. The 'Sacrifice method' (Maynard & Loosli, 1962) was used for determining the water content of the test individuals of both groups in each series before commencement of experiments.

Experiments were conducted in a laboratory, where—except for feeding and observation—there was no disturbance. The number of visits to the surface by each test individual was observed for a known period of time (30 to 45 min), 4 times a day at 7 am, 1 pm, 7 pm and 11 pm. 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. Observations were made daily for a period of 21 days. Since observations were made on 3 individuals in each of the groups belonging to 3 different series, each value presented in Table I represents the average (swimming) performance of a minimum of 250 observations.

Following the Winkler method, estimates on dissolved oxygen content in each aquarium water were made every day at about 9 am. Partial pressure of oxygen (P_{O_2}) was calculated considering 5.65 cc per litre of oxygen as water-saturation point at 27°C (Welch, 1948), which is equivalent to 155 mm Hg (Hughes & Singh, 1971).

Results and discussion

Changes in the P_{O_2}

When kept in water and allowed free access to air, *H. fossilis*, an air-breathing fish, breaths from both media, the intervals between each surfacing are irregular and vary from a few minutes to $\frac{1}{2}$ hr, and are related to oxygen pressure in the water and air (see also Hughes & Singh, 1971). Since water was changed in each aquarium once in 3 days, the respective high oxygen pressure (P_{O_2}) was as high as 139 mm Hg on that day (Table I). The P_{O_2} decreased to different levels in the tested aquaria containing feeding or starving groups on the 1st and 2nd day; for instance, it decreased only to about 118 mm Hg on the 2nd day in the aquaria containing starving groups exposed to different depths; among the feeding groups, there were significant decreases to 34, 56 and 57 mm Hg in the aquaria containing 20, 40, 60 cm depth of water on the 2nd day,

Table 1. Surfacing activity as function of oxygen pressure (P_{O_2}) in the feeding and starving *Heteropneustes fossilis* exposed to different water depths. Each value represents the average performance of minimum 3 individuals (mean \pm SD) observed on 7 different dates for a period of 3 hours/day.

	Number of days after aquarium water change			Mean \pm SD
	0 day	1st day	2nd day	
<i>Depth of water: 20 cm</i>				
a) fed group				
P_{O_2} (mm Hg)	139 \pm 5	54 \pm 5	34 \pm 3	76 \pm 4
Distance travelled (m/day)	130 \pm 36	134 \pm 31	159 \pm 27	141 \pm 32
b) starved group				
P_{O_2} (mm Hg)	139 \pm 5	122 \pm 4	155 \pm 4	125 \pm 4
Distance travelled (m/day)	70 \pm 23	66 \pm 16	60 \pm 12	66 \pm 17
<i>Depth of water: 40 cm</i>				
a) fed group				
P_{O_2} (mm Hg)	139 \pm 5	72 \pm 5	56 \pm 3	89 \pm 5
Distance travelled (m/day)	310 \pm 38	332 \pm 44	372 \pm 43	338 \pm 42
b) starved group				
P_{O_2} (mm Hg)	139 \pm 5	127 \pm 2	116 \pm 7	127 \pm 5
Distance travelled (m/day)	150 \pm 17	130 \pm 22	114 \pm 14	132 \pm 18
<i>Depth of water: 60 cm</i>				
a) fed group				
P_{O_2} (mm Hg)	139 \pm 5	73 \pm 7	57 \pm 5	90 \pm 6
Distance travelled (m/day)	300 \pm 64	318 \pm 56	358 \pm 51	325 \pm 57
b) starved group				
P_{O_2} (mm Hg)	139 \pm 5	129 \pm 3	121 \pm 8	130 \pm 5
Distance travelled (m/day)	93 \pm 11	84 \pm 4	74 \pm 3	86 \pm 6

respectively. On the whole these groups were exposed to an average P_{O_2} of 76, 89, 90 mm Hg. While the starving groups were exposed to an average P_{O_2} of 128 mm Hg, the feeding groups were exposed to an average P_{O_2} of only 85 mm Hg (Table I). The significant decrease observed in the P_{O_2} of aquarium containing feeding groups may be due to the decomposing faeces.

Surfacing response as function of P_{O_2}

Hughes & Singh (1971) observed that when *H. fossilis* is kept in air-saturated water, it rarely surfaced, remaining under the surface for a maximum period of 12 hr. The fish attempted surfacing when the P_{O_2} was reduced between 100 and 50 mm Hg. Such changes in the P_{O_2} decreased the O_2 uptake from 0.06 to 0.04 ml/g/hr at 25°C. In the present study, feeding and starving *H. fossilis* exposed to different depths of aquaria, began to surface usually after an hour of water change in the aquarium, i.e. at 27°C, the fish commenced surfacing even at the P_{O_2} of about 140 mm Hg. The feeding group exposed to 20 cm depth surfaced 326 times/day (Fig. 1) and swam 130 m/day (Table I) on the 0 day, when the P_{O_2} was 139 mm Hg; despite the decrease in the P_{O_2} to 54 mm Hg the fish did not significantly increase the number of surfacing on the 1st day; on the 2nd day, when the P_{O_2} was only 34 mm Hg, the fish, however, increased surfacing to 398 times/day. Similarly, the feeding groups in 40 and 60 cm depths did

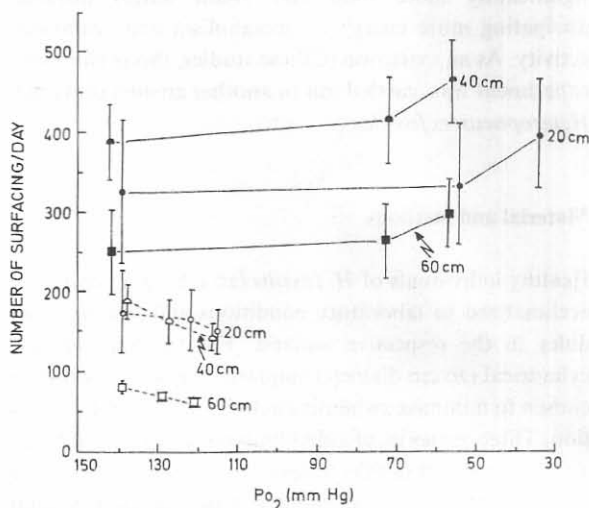


Fig. 1. Effects of the P_{O_2} on the number of surfacing by the feeding (continuous lines) and starving (dotted lines) *Heteropneustes fossilis* exposed to 20 cm (—○—), 40 cm (—●—) and 60 cm (—■—) water depths at 27°C. Each value represents the average performance of minimum 3 individuals (mean \pm SD) observed on 7 different dates for a period of 3 hours/day.

not significantly increase the number of surfacing on the 1st day (Fig. 1), despite the decrease in the P_{O_2} to 72 mm Hg. On the 2nd day, when the P_{O_2} averaged only 56 mm Hg, these groups increased significantly the number of surfacing to 465 and 298 times/day, respectively (Fig. 1). It therefore appears that the decreasing P_{O_2} induces the feeding groups to surface more frequently beyond 70 mm Hg. Response of the starving groups to the decreasing P_{O_2} was, however, different. As the P_{O_2} decreased to about 126 and 117 mm Hg on the 1st and 2nd day, the number of surfacing linearly decreased in all groups (see Fig. 1).

Surfacing and swimming activities

Despite these day-to-day variations in the P_{O_2} and the consequent differences in the surfacing response of the feeding and starving groups exposed to different depths, certain trends became apparent in relation to ration levels and aquarium depths, when the data obtained for the number of surfacing and the distance travelled per day as function of time (21 days) are considered. Table II presents data on the effects of different water depths on swimming activity of the feeding and starving groups. The number of surfacing increased from 353 times/day, when the feeding groups were reared in aquarium containing 20 cm depth of water to 423 times/day in those fish at a depth of 40 cm and correspondingly, the distance travelled also increased from 141 to 338 m/day. However, the group reared in 60 cm depth of water reduced the number of surfacing to 271, swimming only 325 m/day. The starving groups surfaced only 163 times/day and travelled 65 or

130 m/day, when reared in 20 or 40 cm depth of water. Like the feeding groups exposed to 60 cm depth of water, the starving group significantly reduced the number of surfacing to 70 times and the distance travelled to 84 m/day.

On the whole, it appears that feeding and starving *H. fossilis* reduced the number of surfacing, when the distance they have to swim exceeded 0.8 m/surfacing and increased the proportion of oxygen uptake branchially (see Table II). Pandian & Vivekanandan (1976) observed that the obligatory air-breathing fish *Ophiocephalus striatus* progressively increased the surfacing and the distance swam, when they were exposed to deeper and deeper aquaria. After swimming a definite distance, *O. striatus* resorted to a behavioural adaptation of 'hanging' to the surface (3.0 hr for the feeding groups and 15.5 hr for the starving groups) for a definite period of time before returning to the bottom; in addition to the branchial respiration, 'hanging' to the surface permitted *O. striatus* to exchange gas without undertaking vertical migration. Obviously *O. striatus*, as an obligatory air-breathing fish, is not able to alter the proportion of O_2 uptake from water and air. *H. fossilis*, as a facultative air-breather, attempts to maintain the proportion of O_2 uptake from water and air upto a limit, in which the energy cost involved in swimming does not exceed 0.8 m/surfacing, and beyond that it alters the proportion of O_2 uptake more in favour of branchial respiration. Hughes & Singh (1971) reported that *H. fossilis* obtained 59% of its requirements from water and 41% from air, and has considerable powers of

Table 2. Effects of feeding, starvation and surfacing activity on different metabolic parameters in *Heteropneustes fossilis*. Each value represents the average performance of minimum 3 individuals (mean \pm SD) observed for a period of 21 days at 27°C.

	Depth of water (cm)					
	20		40		60	
	Fed	Starved	Fed	Starved	Fed	Starved
Number of surfacing/day	353 \pm 78.4	163 \pm 42.6	423 \pm 52.3	163 \pm 22.2	271 \pm 46.8	70 \pm 5.0
Distance travelled (m/day)	141 \pm 31.4	65 \pm 17.0	338 \pm 41.8	130 \pm 17.9	325 \pm 57.2	84 \pm 6.0
Feeding rate (mg/g/day)	16.9 \pm 1.06	-	18.9 \pm 1.13	-	27.4 \pm 1.77	-
Absorption rate (mg/g/day)	15.1 \pm 0.70	-	16.9 \pm 0.60	-	24.6 \pm 1.55	-
Conversion rate (mg/g/day)	+6.7 \pm 0.55	-1.2 \pm 0.00	+7.2 \pm 0.60	-1.6 \pm 0.10	+7.0 \pm 1.76	-2.9 \pm 0.10
Absorption efficiency (%)	89.9 \pm 2.06	-	90.3 \pm 3.10	-	90.1 \pm 2.58	-
Conversion efficiency (K_2) (%)	44.4 \pm 3.27	-	42.7 \pm 3.90	-	28.5 \pm 5.71	-

reversing the proportion when exposed to different environmental stress.

Rates of feeding and conversion

Feeding rate, which was about 18 mg dry liver/g live fish/day in the groups exposed to 20 and 40 cm depth, increased significantly to 27.4 mg/g/day in the group reared in the maximum depth. Difference in the feeding rates among the groups exposed to 20 and 40 cm depth was not statistically significant ($t = 1.291$; $P < 0.10$); the same is true with regard to number of surfacing. Food absorption efficiency averaged 90.1% and did not appreciably vary between these groups, despite the more than 50% increase in the ration consumed by the group reared in 60 cm depth aquaria (see also Gerking, 1955, 1971; Pandian, 1967; Pandian & Vivekanandan, 1976, Vivekanandan, 1976); hence the trend observed for absorption rate as function of depth of water and ration is parallel to the one obtained for feeding rate against depth of water.

Conversion efficiency (K_2) was about 43% in the groups exposed to 20 and 40 cm depth and the observed difference among them was not statistically significant ($t = 0.475$; $P < 0.10$). The 43% efficiency is one of the highest values so far reported. The other high values reported in the literature are 37% for the yearling cutthroat trout *Salmo clarkii* (Warren & Davis, 1967), 44% (Pandian, 1967), 35% (Vivekanandan et al., 1976) for the young (1 g) *O. striatus* fed on prawn or goat liver. Values from the Cortland Hatchery Reports (1952) for the trouts fed on different combinations of cattle liver, also suggest such high values.

H. fossilis, reared in 60 cm depth aquaria, however, showed significantly low conversion efficiency of 28.5%, although they consumed significantly more food and reduced the number of surfacing activity. Similarly, the starved group also exhibited a maximum loss of 2.9 mg dry fish substance/g live fish/day, as against about 1.4 mg/g/day expended on metabolic processes by the starving groups in the aquaria containing 20 and 40 cm depth of water. Therefore, it appears that the feeding groups exposed to 60 cm depth were spending relatively more energy on such processes as the Specific Dynamic Action (SDA- net energy loss owing to the processes of digestion, movement and food deposition, and deamination of non-utilized assimilated energy; Warren & Davis, 1967), if not on the surfacing activity. Since *H. fossilis* reared in aquaria containing 40 cm depth exhibited a maximum conversion rate of 7.2 mg/g/day and a high conver-

sion efficiency of 42.7%, cultivation in shallow waters of 40 cm depth may promote efficient and rapid growth.

Summary

Reared in tubular aquaria containing 20, 40 and 60 cm depth of water, *Heteropneustes fossilis* (20 g; 17 cm body length), an air-breathing catfish, swam 40, 80 and 120 cm/surfacing to exchange atmospheric air. With decreasing P_{O_2} , the starving groups reduced the surfacing, whereas, the decrease in the P_{O_2} beyond 70 mm Hg induced the feeding groups to surface more frequently. Feeding groups exposed to 20 and 40 cm depth surfaced 353 and 423 times, travelling distances of 141 and 338 m/day, at the energy cost of 8.5 and 9.7 mg dry fish substance/g live fish/day, respectively. The corresponding starving groups surfaced only 163 times/day and swam 65 and 130 m/day at the expense of 1.2 and 1.6 mg/g/day. Feeding and starving groups reduced the number of surfacing, when the distance they have to swim exceeded 0.8 m/day and increased the proportion of O_2 taken up branchially; the starving and feeding groups exposed to 60 cm depth surfaced only 70 and 271 times, swimming 84 and 325 m/day, at the energy cost of 2.9 and 17.6 mg/g/day. Feeding and conversion rates steadily increased from 16.9 mg dry liver/g live fish/day and 6.7 mg dry fish substance/g live fish/day in those exposed to the shallowest aquarium to 27.4 mg/g/day and 7.0 mg/g/day in those exposed to the maximum depth, respectively; conversion efficiency was 44% in the former and 28% in the latter; hence culturing *H. fossilis* in the shallow waters is profitable.

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