Hydrobiologia vol. 52, 2-3, pag. 165-169, 1977

EFFECTS OF THE pO_2 ON SWIMMING ACTIVITY AND FOOD UTILIZATION IN OPHIOCEPHALUS STRIATUS

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Received January 13, 1976

Keywords: Ophiocephalus. Air-breathing fish. Food conversion. metabolic efficiency.

Abstract

The obligatory air-breathing fish *Ophiocephalus striatus*, fed on goat-liver, surfaced 906 times, swimming 270 m/day in aerated water (mean pO_2: 151 mm Hg) and 883 times, travelling 325 m/day in non-aerated water (92 mm Hg); surfacing and swimming activities increased below the pO_2 of 74 mm Hg. Hanging duration was more (8.4 hr/day) in the aerated series than that in the non-aerated series (5.9 hr/day). Rates of feeding, absorption and metabolism of either series averaged to 131, 126 and 93 (= 0.8 ml O_2/g/hr) g cal/g live fish/day. Conversion rate and efficiency slightly increased from 22 g cal/g/day and 17 % in the aerated series. Culturing *O. striatus* in aerated waters may not be advantageous. Starving groups in the aerated and non-aerated aquaria surfaced 317 times, hung for 14.7 hr, and swam 61 m/day, expending 15 g cal/g/day (= 0.1 ml O_2/g/hr).

Introduction

This paper is based on previous studies dealing with the effect of partial pressure of oxygen (pO_2) on surfacing activity and food utilization of air-breathing fishes like *Anabas scandens* (Pandian *et al.*, 1976) and *Heteropneustes fossilis* (Arunachalam *et al.*, 1976). Pandian *et al.* (1976) showed that the pO_2 of water altered the surfacing activity, but not the rate and efficiency of food utilization in *A. scandens*. As an extension of these publications, the present experiment was carried out with the obligatory air-breathing fish *Ophiocephalus striatus* to study whether food quality modifies both swimming activity and food utilization pattern or any one of them.

Dr. W. Junk b.v. Publishers - The Hague, The Netherlands

Material and methods

The experimental design described by Pandian *et al.* (1976) was followed in the present study. *Ophiocephalus striatus* (15.3 ± 0.65 g; 10.3 ± 0.4 cm body length) was reared in cylindrical (15.2 cm diameter) aquaria (volume: 4.5 l). A translucent glass plate (14.5 cm breadth; 30 cm height) was introduced into the aquarium; on one side of the glass partition, water was aerated and the fish was confined to the other side; water could move through the space available between the wall of the aquarium, and the partition. Depth of water in the aquaria was kept constant (25 cm).

The test individuals comprised 2 series – one series was accomodated in aquaria aerated throughout the experiment, while the other was not aerated. In each series, one group was starved; the other group was fed *ad libitum* on pieces of goat-liver twice a day for a period of 1 + 1 hr; each group comprised of 6 individuals. Unfed liver was collected using a pipette. Faeces were collected by filtering the entire aquaria once in 5 days. The 'sacrifice method' (Maynard & Loosli, 1962) was used for determining the water content of the test individuals of both groups in either series before commencement of the experiment. Calorific content was determined using a Parr 1412 Semimicro bomb calorimeter, following the standard procedure described in the instruction manual Nos. 128 and 130.

Number of surfacing as well as hanging frequency and duration of each test individual were observed for a known period of time (30 min each), 4 times a day at 7 am, 1 pm, 7 pm and 11 pm. The distance travelled per individual was determined by multiplying the mean number of visits per unit observation time with twice the depth of water and then correcting it for hanging duration.

Water was changed in the aquarium once in 5 days, excepting on the 25th day of the experiment, when the aquaria were left for 7 days without changing water. Dissolved oxygen content (ml/l) was estimated every day at about 3 pm following the unmodified Winkler method (Welch, 1948). Following Pierce *et al.* (1973), the O_2 content value was converted to partial pressure of oxygen.

Results and discussion

Fluctuations in the pO_2 of water

Since water was changed in each aquarium once in 5 days, the respective values obtained for the pO_2 on the 0, 1st, 2nd, 3rd and 4th day after aquarium water change were separately averaged (in the aquaria containing feeding groups) and are given in Table I; the values obtained for the final 7 days are given separately (Table I). The significant drop in the pO_2 of the non-aerated aquaria containing the feeding group may be due to decomposing faeces. On an average, the fed and starved groups in the aerated series enjoyed the pO_2 of 151 and 152 mm Hg, while those in the non-aerated series were exposed to a pO_2 of 92 and 121 mm Hg, respectively (Table II).

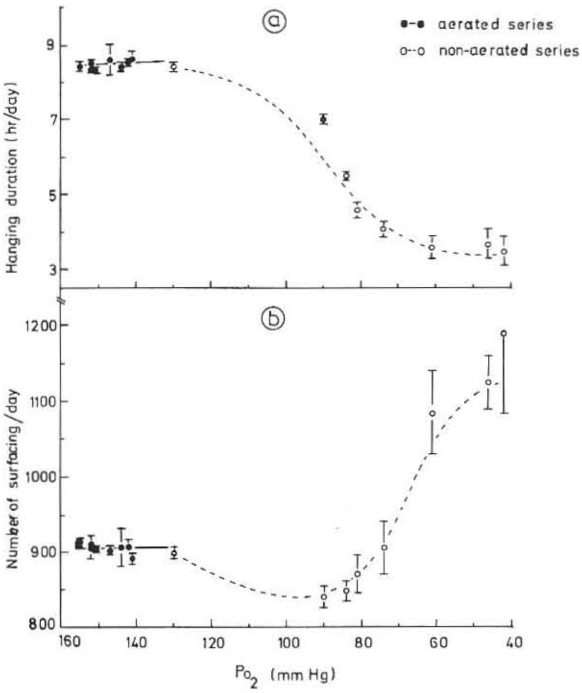

Fig. 1. Effects of the Po_2 on number of surfacing (b, lower panel) and hanging duration (a, upper panel) of the feeding *Ophiocephalus striatus* reared in aquaria containing aerated (continuous lines) and non-aerated (dotted lines) waters at 27°C. Each value represents the average performance of 6 individuals; vertical lines indicate SD.

Surfacing activity

Though the feeding and starving groups in the aerated series enjoyed an average pO_2 of 151 mm Hg, they still surfaced once every 1.6 and 4.6 min, respectively; this clearly shows that the gills are inadequate to supply the required oxygen entirely from water. Under similar experimental conditions, Pandian *et al.* (1976) made similar observation on the air-breathing fish *Anabas scandens*; at a pO_2 of 150 mm Hg, the feeding and starving *A. scandens* surfaced once every 1.7 and 4.2 min, respectively.

The pO_2 in the non-aerated aquaria, in which *O. striatus* was fed, decreased from 130 mm Hg on the 0 day to 74 mm Hg on the 4th day after aquarium water change (Table I). The surfacing activity ranged from 899 time/day on the 0 day to 843 time on the 1st day and averaged to 883 time/day for the first 5 day period, but there was no significant difference in the surfacing frequency during this period (e.g. 0 day vs 3rd day: $t = 2.164$, $P > 0.05$). However, the steady increase in the frequency from 905 time at the pO_2 of 74 mm Hg on the 4th day to 1183 time/day at the pO_2 of 42 mm Hg on the 7th day is highly significant ($t = 5.524$, $P < 0.001$) and bears a direct relation to the dropping pO_2 from 74 to 42 mm Hg (Fig. 1). The changes in the surfacing frequency, which was not directly related to the changes in the pO_2 during the initial 4 days (Table I), was considered to be negligible.

Hill *et al.* (1972) also stated that the young dipnoan fish *Lepisosteus oculatus* (at 18°C) increased its surfacing frequency from about 190 time/day at the pO_2 of 80 mm Hg to over 480 time/day, when the pO_2 decreased below 79 mm Hg. The bowfin *Amia calva* increased the frequency of surfacing to over 1200 time/day below 100 mm Hg at 30°C (Johansen *et al.*, 1970). Pandian *et al.* (1976) reported that when the pO_2 decreased below 60 mm Hg, *Anabas scandens* increased the surfacing from 550 to 650 time/day at 27°C. The facultative air-breathing catfish *Heteropneustes fossilis* increased its surfacing frequency, when the pO_2 decreased below 70 mm Hg at 27°C (Arunachalam *et al.*, 1976). Hence, a pO_2 below the range of 80 to 60 mm Hg may be the critical level, at which the

Table I. Effect of the Po_2 on swimming activity in *Ophiocephalus striatus* (15.3 ± 0.65 g) fed on goat-liver. Each value represents the average performance of 6 individuals (mean ± SD) observed on 7 different dates

Number of days after aquarium water change	Aerated				Non-aerated			
	Po_2 (mm Hg)	Number of surfacing/day	'Hanging' duration (hr/day)	Distance travelled (m/day)	Po_2 (mm Hg)	Number of surfacing/day	'Hanging' duration (hr/day)	Distance travelled (m/day)
Initial 25 day period								
0	155 ± 0.0	912 ± 4.7	8.4 ± 0.13	296 ± 1.2	130 ± 2.1	899 ± 11.7	8.4 ± 0.11	283 ± 2.2
1	152 ± 2.8	907 ± 9.3	8.5 ± 0.13	285 ± 2.1	90 ± 4.8	843 ± 14.7	7.0 ± 0.10	299 ± 3.1
2	152 ± 1.1	904 ± 13.3	8.4 ± 0.13	276 ± 2.5	84 ± 2.6	897 ± 15.2	5.5 ± 0.09	335 ± 4.3
3	151 ± 3.6	904 ± 8.0	8.3 ± 0.15	277 ± 1.1	81 ± 1.3	872 ± 24.9	4.6 ± 0.18	353 ± 9.8
4	147 ± 3.0	901 ± 4.0	8.6 ± 0.45	268 ± 0.9	74 ± 1.3	905 ± 36.0	4.1 ± 0.24	376 ±14.0
Mean	151 ± 2.1	906 ± 7.9	8.4 ± 0.20	280 ± 1.6	92 ± 2.4	883 ± 20.5	5.9 ± 0.14	329 ± 6.7
Final 3 day period (26th day to 28th day)								
5	144 ± 1.0	906 ± 26.6	8.4 ± 0.10	272 ± 5.1	61 ± 2.1	1085 ± 55.7	3.6 ± 0.33	462 ±24.6
6	142 ± 3.0	905 ± 10.2	8.5 ± 0.13	279 ± 1.9	46 ± 1.3	1126 ± 34.6	3.7 ± 0.42	476 ±11.7
7	141 ± 2.0	891 ± 8.0	8.6 ± 0.19	286 ± 2.4	42 ± 1.4	1183 ± 93.9	3.5 ± 0.35	505 ±43.6

air-breathing fishes switch over to a more frequent surfacing to obtain proportionately more oxygen from atmospheric air (see Johansen, 1970).

Despite the day-to-day fluctuations in the pO_2 of water and the consequent differences in the surfacing activity of the feeding and starving groups, the values obtained for the different groups for the 4 days after aquarium water change were averaged and are given in Table II. Among the feeding groups, the surfacing activity decreased from 906 time/day in the aerated series to 883 time/day in the non-aerated series; however, this decrease was not statistically significant ($t = 1.136$, $P > 0.10$); the starving groups also failed to exhibit a marked difference in surfacing activity (about 317 time/day) among themselves.

Table II. Effects of the Po_2 on swimming activity and food utilization in *Ophiocephalus striatus* (15.3 ± 0.65 g). Each value represents the average performance of 6 individuals (mean ± SD) observed for a period of 28 days at 27°C

Parameters	Aerated		Non-aerated	
	Fed	Starved	Fed	Starved
	Po_2: 151 mm Hg	Po_2: 152 mm Hg	Po_2: 92 mm Hg	Po_2: 121 mm Hg
Number of surfacing/day	906 ± 29.6	316 ± 24.0	883 ± 33.2	318 ± 31.7
Hanging frequency (time/day)	89 ± 18.3	63 ± 4.7	92 ± 20.9	65 ± 18.3
Hanging duration (hr/day)	8.4 ± 0.06	14.7 ± 0.07	5.9 ± 0.09	14.7 ± 0.12
Distance travelled (m/day)	270 ± 9.7	61 ± 4.6	325 ± 12.8	61 ± 6.1
Feeding rate (g cal/g/day)	133.3 ± 3.33	-	128.7 ± 0.00	-
Absorption rate (g cal/g/day)	127.8 ± 1.42	-	124.1 ± 1.19	-
Conversion rate (g cal/g/day)	+21.6 ± 1.13	-14.2 ± 0.52	+24.1 ± 1.65	-16.0 ± 0.26
Metabolic rate (g cal/g/day)	95.6 ± 4.19*	14.2 ± 0.52	90.0 ± 3.14*	16.0 ± 0.26
Metabolic rate (ml O_2/g/hr)	0.83± 0.04	0.12 ± 0.01	0.79± 0.03	0.14 ± 0.01
Absorption efficiency (%)	95.9 ± 1.97	-	96.4 ± 1.21	-
Conversion efficiency (K_2) (%)	16.9 ± 1.00	-	19.4 ± 1.28	-

* Values represent the amount of absorbed food minus the amount of ammonia and urine (9.85% of the food consumed) excreted (Solomon & Brafield, 1972)

Hanging

After few surfacings, *O. striatus* remains just below the water surface for a definite period and exchanges atmospheric air without undertaking vertical movement; such 'hanging' is considered as a behavioural adaptation (Pandian & Vivekanandan, 1976; Vivekanandan, 1976). Observations made on the hanging duration revealed that the feeding group in the non-aerated series hung for a longer time (8.4 hr/day) at the pO_2 of 130 mm Hg than at 42 mm Hg (3.5 hr/day) (Table I; Fig. 1). It is interesting to note that *O.striatus* did not opt to stay near the surface for a longer duration, even when the pO_2 is as low as 42 mm Hg.

Mean hanging duration of the feeding series during the initial 5 day period after aquarium water change was significantly longer in the aerated series (8.4 hr/day; Table II) than that in the non-aerated series (5.9 hr/day) ($t = 35.715$; $P < 0.001$).

The number of hanging was almost equal (about 90 time/day) for the feeding groups of the aerated and non-aerated series; the same was true for the starving groups of either series (64 time/day) (Table II). In other words, the feeding groups hung once every 10 surfacings and each hanging lasted for about 5 min; the starving groups hung once every 5 surfacings and each hanging lasted for about 13 min.

Swimming activity

Swimming activity of the feeding series steadily increased from 283 m/day at the pO_2 of 130 mm Hg to 505 m/day at the pO_2 of 42 mm Hg in the non-aerated series (Table I). The difference between the mean distance swum by the feeding series in the non-aerated and aerated aquaria (Table II) during the 4 day period after aquarium water change was statistically significant ($t = 7.686$, $P < 0.001$). The feeding series in the non-aerated aquaria swam relatively a longer distance (325 m/day); it could have reduced the distance swum, had it resorted to hanging to the surface for a longer duration. It is not clear why the fish did not resort to such behavioural adaptation of hanging for a longer duration. Conversely, the feeding group in the aerated aquaria vertically swam a shorter distance (270 m/day) by increasing the hanging duration; had it not resorted to hanging for a longer duration, it might have had to swim an almost equal distance, as that in the non-aerated series.

The starving groups of aerated and non-aerated series swam an equal distance (61 m/day) to exchange atmospheric air. It may be concluded that the pO_2 of water did not affect the surfacing and swimming activities of the starving groups.

Food utilization

Feeding rate averaged to 131 g cal/g live fish/day for both the aerated (pO_2: 151 mm Hg) and non-aerated (92 mm Hg) series; hence continuous aeration did not influence food intake significantly; Pandian *et al.* (1976) too found no significant difference in the food intake of *A. scandens*, when reared at different pO_2 levels (142 to 66 mm Hg). The northern pike *Esox lucius* was observed to consume 250 mg dry food/g dry fish/day at a pO_2 of 120 mm Hg and 110 mg/g/day at a pO_2 of 28 mm Hg (Adelmann & Smith, 1970). The decreased food consumption of *E. lucius* may be due to the fact that it was tested at far lower pO_2 than that tested either for *O. striatus* or for *A. scandens*.

Rate and efficiency of absorption in *O. striatus* averaged to about 126 g cal/g/day and 96.2%, respectively, and did not appreciably vary among the two series (Table II).

Conversion rate and efficiency increased from 21.6 g cal/g/day and 16.9% in the aerated series to 24.1 g cal/g/day and 19.4 % in the non-aerated series, respectively. In the non-aerated water, *O. striatus* appears to be a slightly more efficient convertor. Herrmann *et al.* (1962), who made similar observation in the juvenile coho salmon *Oncorhynchus kisutch,* concluded that at low pO_2 levels, the fish converted efficiently, as they could afford to lower the maintenance requirements.

Changes in the mean pO_2 between 151 (aerated) and 92 (non-aerated) mm Hg did not significantly influence the rate and efficiency of food utilization in *O. striatus*. However, the publications of Herrmann *et al.* (1962) and Adelmann & Smith (1970) suggest that if *O. striatus* is also exposed to still lower pO_2, it might consume less food but convert more efficiently.

O_2 uptake

While energy expended on the metabolic processes by the feeding *O. striatus* in either series was equivalent to 0.81 ml O_2 uptake/g/hr (= 93 g cal/g/hr), that expended by the starving groups amounted to 0.13 ml O_2/g/hr (15.1 g cal/g/day) (Table II). These values are relatively higher than those reported by Pandian *et al.* (1976) for *A. scandens*, the D_2 uptake of the feeding *A. scandens* averaged to 0.58 ml/g/hr and that of the starving fish 0.07 ml/g/hr in the aerated and non-aerated series.

Acknowledgement

I am grateful to Dr. T. J. Pandian for valuable guidance. This work was commenced during the tenure of my CSIR (New Delhi) Senior Fellowship (Grant No. 7/325 (2)/74-EMRI) and completed under the UGC (New Delhi) grant awarded to Dr. T. J. Pandian (Grant No. F.23-210/75 (SR II), and I express appreciation to both these agencies.

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