Neotropical Ichthyology, 4(3):371-373, 2006

Scientific note

The air-breathing cycle of *Hoplosternum littorale* (Hancock, 1828) (Siluriformes: Callichthyidae)

Ricardo Jucá-Chagas and Lilian Boccardo

Hoplosternum littorale is a continuous air breather, which uses a portion of its intestine to extract oxygen from inspired air. Its air-breathing behavior occurs in four phases: 1) ascent to the water surface; 2) mouth emergence with expansion of the oral cavity for air inspiration; 3) downward swimming and oral cavity compression resulting in air swallowing and the expiration of old air from the anus; 4) return to bottom. The time required to complete the air-breathing cycle was significantly shorter for small fish compared to large fish.

Hoplosternum littorale é um peixe de respiração aérea continua que utiliza parte de seu intestino para a extração do oxigênio do ar. Este comportamento de respiração aérea realiza-se em quatro etapas: 1) Subida para a superfície da água; 2) Emergência da boca com a simultânea expansão da cavidade oral e inspiração; 3) Giro do corpo para baixo com compressão da cavidade oral e expiração do ar pelo ânus; 4) Retorno ao fundo. O tempo necessário para a realização do ciclo respiratório aéreo completo foi significativamente mais curto em indivíduos de menor tamanho quando comparados aos de maior massa corpórea.

Key words: Respiratory organ, Tamboatá, Behavior, Body size, Intestine.

The accessory respiratory organs used by air-breathing fish include lungs, the gas bladder, gills, diverticula formed in the oral-pharyngeal, branchial, and opercular cavities, and the digestive tract (Graham, 1997). The air-breathing behavior of a fish depends on its type of air-breathing organ and is affected by ambient conditions, the depth of the water it is in and the distance (relative to body length) from the fish to the surface (Gradwell, 1971; Kramer & Graham, 1976; Gee & Graham, 1978). This report details aspects of the air-inspiratory behavior of the tamboatá, *Hoplosternum littorale* (Hancock), a Neotropical fish that uses its intestine as an air-breathing organ. Previous studies on *Hoplosternum* have demonstrated that air breathing in normoxic water may be obligatory or non-obligatory in different species, that groups of this species exhibit synchronous air-breathing behavior, and that expired air breaths are discharged from the anus (Gee & Graham, 1978; Graham, 1997). A recent study has further demonstrated a greater per air breath oxygen extraction capacity for *H. littorale* than for two other sympatric air breathers, the jeju (*Hoplerythrinus unitaeniatus*) and the lungfish (*Lepidosiren paradoxa*), suggesting that this difference may be related to features of its blood-oxygen affinity or its one-way air ventilation (Weber *et al.*, 2000; Jucá-Chagas, 2004).

Eight *H. littorale* specimens, four juvenile (3.76 to 9.00 g) and four adult specimens (116.50 to 138.50 g), were collected from a pond in Jequié, Bahia, Brazil (13º52'33.7" S; 40º03'43. 1" W) and transported to the laboratory where they were kept in separate tanks (25ºC, pO_2 <5 mmHg) and fed daily on earthworms and chopped fish. Voucher specimens were deposited in the fish collection of the Laboratório de Ecologia, Universidade Estadual do Sudoeste da Bahia (UESB), Jequié, Bahia, Brazil (PRC-203-204).

Air-breathing cycles were observed for fish placed in an observation tank (70 x 40 x 25 cm, length x width x depth) filled with hypoxic (PO_2 <5 mmHg) water (25ºC). An S-VHS video recorder was used to record the air-breathing cycles and de-

Departamento de Ciências Biológicas, Universidade Estadual do Sudoeste da Bahia, Avenida José Moreira Sobrinho, s/n, 45206-190 Jequié, Bahia, Brazil. e-mail: rjchagas@uesb.br

tails of the behavior were observed. Each fish was transferred to the tank 24 h before the beginning of observation and was observed for at least 1 h over a 2 h period. Observations were made in a dark room to reduce the effect of the observer on fish behavior.

The air-ventilation cycle of *H. littorale* (Fig. 1) consists of four phases. Phase 1 consists of ascent to the surface which can be either direct or the fish may swim from one side to the other as it rises to the surface. This behavior is similar to that described for the armored catfish *Hypostomus punctatus* (Gradwell, 1971). On the surface, the fish opens its mouth, expands the oral cavity and inspires air (phase 2). As new air is inspired, the release of old air from the anus commences and, as the fish turns toward the bottom (phase 3), it compresses its oral cavity, which facilitates transmission of the air into the intestine and forces more air out of the anus. As the fish descends toward the bottom (phase 4), additional gas is expelled from the operculum. Unlike the variable ascent pattern, the descent is direct.

Both closure of the opercula and compression of the oral chamber appear necessary for swallowing the gas and forcing it into the intestine. The nearly simultaneous occurrence of inhalation and expiration further appears to minimize the potential for the mixing of old and fresh air and thus elevates the oxygen diffusion gradient within the intestine (Gee & Graham, 1978; Jucá-Chagas, 2004).

Table 1 shows that the time required to complete the air-breathing cycle was significantly ($p<0.05$, U test) shorter (4.5 s) for small fish compared to large fish (8.9 s). Because both groups were required to swim the same distance (25 cm up, 25 cm down), this means that smaller fish had both fast absolute (cm s^{-1}) and relative (body length s^{-1}) swimming speed. This difference may reflect the relative vulnerability to predation of smaller fish and the importance of synchronous air breathing as a defense mechanism (Gee & Graham, 1978; Graham, 1997).

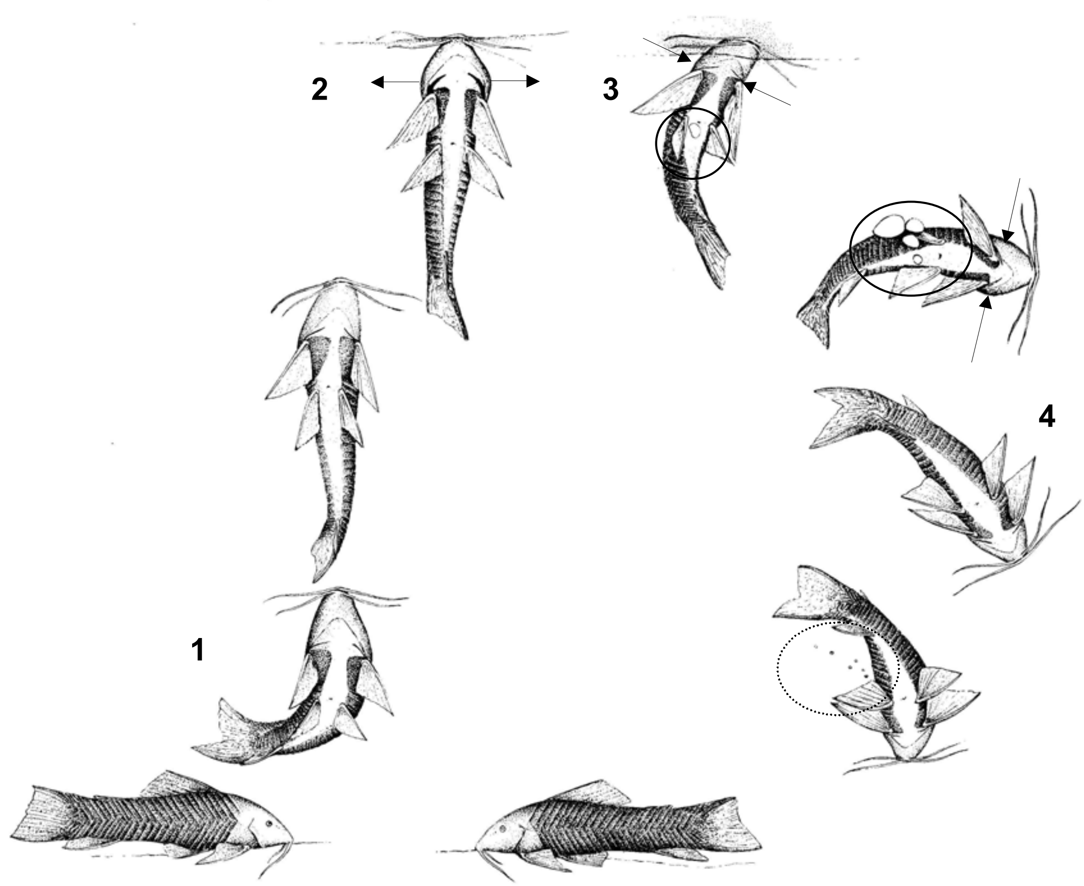

Fig. 1. Air-breathing cycle of *Hoplosternum littorale*: 1) ascent to the water surface; 2) in contact with the surface the fish expands its oral cavity, inspiring air; 3) turning head down, with compression of the oral cavity pushing air into the intestine and causing the expiration of old air from the anus (circle, continuous line); 4) return to bottom and release of small air bubbles through the opercula (circle, dotted line). Arrows indicate the action of the buccal pump.

Table 1. Body weight and the duration of the air-breathing cycle in smaller and larger individuals of *Hoplosternum littorale*. *Significantly different between groups (U-test, p<0.05).

Group	Body weight (g)	Time interval (s) (mean ± S.E.)
Smaller	3.76	4.19 ± 0.86
	5.50	4.91 ± 0.38
	6.26	4.28 ± 0.49
	9.00	4.63 ±.040
Mean ± S.E.	6.13 ± 1.09*	4.50 ± 0.17*
Larger	116.50	9.75 ± 0.69
	120.27	6.95 ± 0.13
	124.50	8.01 ± 0.56
	138.50	10.71 ± 1.32
Mean ± S.E.	124.94 ± 4.81*	8.86 ± 0.85*

Acknowledgments

We thank Jaime Somera for preparing the illustration and Jeffrey B. Graham (University of California, USA) for reading drafts of the manuscript.

Literature Cited

Gee, J. H. & J. B. Graham. 1978. Respiratory and hydrostatic functions of the intestine of the catfishes *Hoplosternum thoracatum* and *Brochis splendens* (Callichthyidae). Journal of Experimental Biology, 74: 1-16.

Gradwell, N. 1971. A photographic analysis of the air breathing behavior of the catfish, *Plecostomus punctaus*. Canadian Journal of Zoology, 49: 1089-1094.

Graham, J. B. 1997. Air-breathing fishes: evolution, diversity, and adaptation. Academic Press, San Diego, 320p.

Jucá-Chagas, R. 2004. Air breathing of the neotropical fishes *Lepidosiren paradoxa*, *Hoplerythrinus unitaeniatus* and *Hoplosternum littorale* in aquatic hypoxia. Comparative Biochemistry and Physiology, Part A, 139: 49-53.

Kramer, D. L. & J. B. Graham. 1976. Synchronous air breathing, a social component of respiration in fishes. Copeia, 1976: 689-697.

Weber, R. E., A. Fago, A. L. Val, A. Bang, M. L. Van Hauwaert, S. Dewilde, F. Zal & L. Moens. 2000. Isohemoglobin differentiation in the bimodal-breathing Amazon catfish *Hoplosternum littorale*. Journal of Biological Chemistry, 275: 17297-17305.

Received March 2006
Accepted August 2006