

**TO BREATHE OR NOT TO BREATHE, THAT IS THE QUESTION:
AIR BREATHING BEHAVIOR AND PHYSIOLOGY OF HYPOXIC**

HYPOSTOMUS

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EXTENDED ABSTRACT ONLY-DO NOT CITE

The Neotropical catfish family Loricariidae is a vertebrate success story about which we know little. With over 600 described species (and many additional undescribed) this family evolved entirely after the Cretaceous separation of South America from Africa and accounts for between 1 and 2% of all current vertebrate diversity. Unlike other speciose fish families that usually exploit multiple trophic niches, virtually all loricariids are herbivorous and eat near the bottom of the food chain. Field collections and laboratory experiments suggest that some loricariid catfishes are even utilizing wood in their diet (Nelson *et al.* 1999). This is the first and only documentation of wood eating (xylophagy) in the more than 25,000 species of bony fish. Despite the evolutionary success of the Loricariidae and their interesting biology, very little is known about them. The small amount of physiological work directed at loricariids has primarily concerned their adaptations to the hypoxic (and recently, acidic) waters found in Amazonia (e.g. Graham and Baird, 1982; Mattias *et al.* 1998). Relatively little attention has been directed towards the nutritional physiology or trophic ecology of these fishes (Araujo-Lima *et al.* 1986).

Interestingly, all cellulolytic organisms thus far cultured from loricariids are either aerobic or facultatively anaerobic and all loricariids that have been tested are facultative air breathers that use their gut for a gas exchange organ. Thus, it is possible that loricariids are the only vertebrates to be digesting cellulose under aerobic conditions. Unfortunately, nothing is known about the gut environment of loricariids and whether air breathing has any influence on it. Since further progress in understanding the digestive processes of loricariids requires having some fundamental information about the environment of the gastrointestinal tract, one goal of this study was to characterize the gut

environment under both air breathing (water $PO_2 = 20$ torr) and water breathing conditions (normoxia).

Individual *Hypostomus regani* were fitted with EKG electrodes and a buccal catheter and placed in a chamber that allowed monitoring of surfacing events. Data were collected with appropriate electrodes and transducers coupled to Maclab recording equipment. Animals were either exposed to 3 hours of normoxia or 1 hour of normoxia followed by 3 hours of hypoxia (water $PO_2 = 20$ torr). Upon completion of the prescribed period, animals were anaesthetized with a concentrated solution of benzocaine administered through the buccal catheter and then removed for sampling of blood and gut contents.

Venous blood pH was constant around 8 for all treatments and venous blood PO_2 was about 10 torr in hypoxic and 30 torr in normoxic animals. All digestive tract pH values were near neutral and the gut was oxygenated under air and water breathing conditions.

The normoxic heart rate of *Hypostomus regani* was about 100 bpm and respiratory frequency averaged 170 bpm. Hypoxia initiated a sustained bradycardia that gradually ameliorated over a three-hour period, but hypoxia did not affect respiratory frequency. Coincident monitoring of air-breathing activity and heart rate split the hypoxic animals into two groups, those that had a predilection for air breathing and those that "preferred" to remain submerged most of the time. The former were characterized by more than 10 surfacing events over a three-hour period, a first surfacing event at about fifteen minutes of hypoxic exposure and a more frequent and dramatic "surfacing tachycardia" (Figure 1). The latter were distinguished by less than 10 surfacing events in a three hour period, a first surfacing event at about thirty minutes of hypoxic exposure and an initially nonexistent "surfacing tachycardia" that gradually increased with hypoxic exposure (Figure 1).

These results clearly show that air breathing behaviour and its physiological support in *Hypostomus* are largely determined at the individual level. Despite dramatic differences in air-breathing behaviour, blood and gut oxygen and pH levels were maintained at relatively constant levels across treatments.

Figure 1: post-breath tachycardia in hypoxic *Hypostomus*

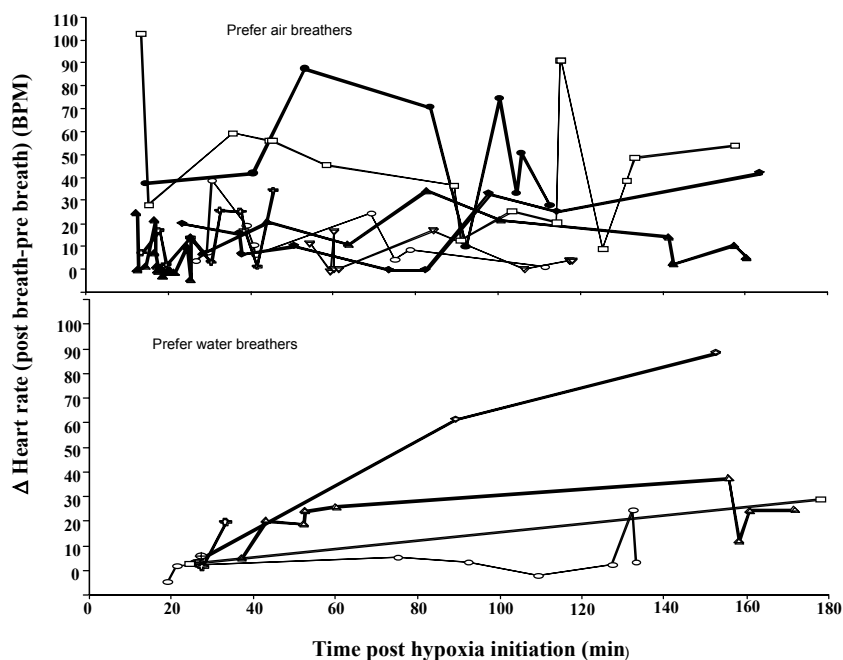


Figure 1: Heart rate changes in individual *Hypostomus regani* exposed to 20 torr PO_2 for three hours. Each symbol represents the time of an individual air-breathing episode for an individual plotted as the difference in heart rate immediately before and after the surfacing event. The upper panel contains those animals that frequently surfaced (>10) and the bottom panel those animals that surfaced infrequently.

Literature cited

Araujo-Lima C.A.R.M., B.R. Forsberg, R. Victoria, and L. Martinelli (1986). Energy sources for Detritivorous fishes in the Amazon. *Science* 234: 1256-1258.

- Graham, J.B. & T.A. Baird (1982). The transition to air breathing in fishes. **J. Exp. Biol.** 96:53-67.
- Mattias, A.T., Rantin, F.T. & Fernandes, M.N. (1998). Gill respiratory parameters during progressive hypoxia in the facultative air-breathing fish, *Hypostomus regani* (Loricariidae). **Comp. Biochem. Physiol.**, 120(A):331-315.
- Nelson, J.A., D.J. Stewart, M.E. Whitmer, E.A. Johnson & D. Wubah (1999). Wood-eating catfishes and their aerobic, cellulolytic gut symbionts: ecological and evolutionary implications. **J. Fish Biol.** 54: 1069-1082.