

**CARDIO-RESPIRATORY, METABOLIC AND BEHAVIOURAL
ASPECTS OF HYPOXIA SURVIVAL IN THE AMAZONIAN
ARMOURED CATFISH *GLYPTOPERICHTHYES GIBBICEPS***

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EXTENDED ABSTRACT ONLY – DO NOT CITE

The facultative air breathing armoured catfishes of the Amazon drainage basin exhibit exceptional cardiac tolerance to anoxia and reoxygenation (Bailey et al., 1999). This observation is surprising, since air breathing can contribute up to

70% of arterial O₂ content during hypoxia (Val, 1995), uncoupling environmental and systemic oxygen debt (Brauner et al., 1995). Previous studies suggest that anaerobic heart function in these fish may be preserved by activation of ATP-sensitive K⁺ channels (MacCormack, T.J., Treberg, J., Almeida-Val, V.M.F., Val., A.L. and Driedzic, W.R., submitted for publication) and a high glycolytic capacity. In addition, the high levels of hexokinase (West et al., 1999), the first step in glucose utilisation, imply a high reliance on carbohydrates as a metabolic fuel when oxidative metabolism is impaired.

Anecdotal evidence suggests that *Glyptoperichthyes gibbiceps*, a representative species of air breathing armoured catfish, has formidable hypoxia tolerance, even when denied aerial respiration. The purpose of this study was to assess the basic mechanisms employed by *G. gibbiceps* to survive the frequent periods of hypoxia associated with life in the Amazon. Animals (body mass 324 ± 14g) were fitted with radiotelemetry tags, maintained in field cage sites and tracked over several days to study their habits of depth selection and air breathing. Fish were also subjected to hypoxia and hyperoxia (induced by surface vegetation) in a laboratory pond. Observations were made over a 24 hr period on heart rate (f_h), measured by electrocardiography, and ventilation rate (f_v), measured using impedance electrodes. In a third level of study, fish kept in Perspex chambers were denied access to aerial respiration and forced to endure a similar level of hypoxia and reoxygenation (using N₂ gas). Data were also collected on plasma glucose and lactate under all test conditions.

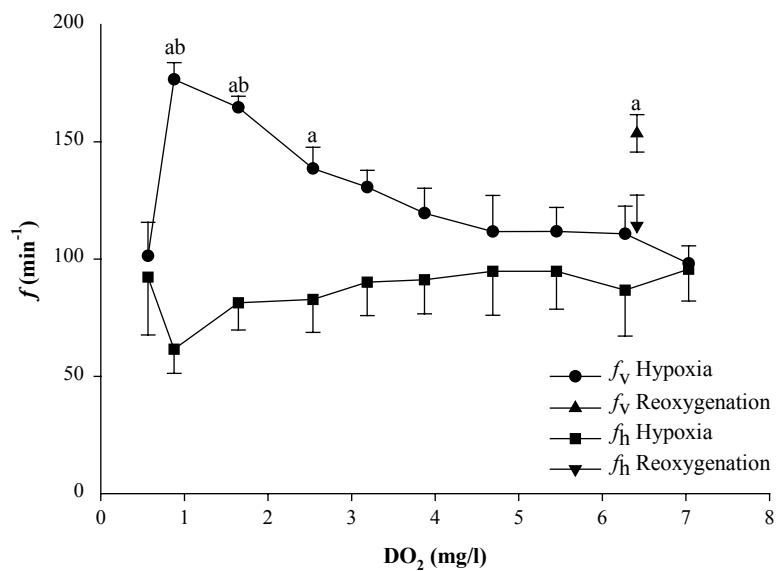
f_h and f_v during hypoxia and reoxygenation in aquaria

Neither hypoxia nor reoxygenation resulted in any significant change in f_h when *G. gibbiceps* were subjected to hypoxia and reoxygenation and denied surface access under laboratory conditions (n = 6, Fig. 1). A similar response was observed for *L. pardalis* (MacCormack et al., submitted), although f_h tended to be lower in that species. Hypoxia resulted in a significant increase in f_v of up to 56% at 0.88 mg/L DO₂ (Fig. 1). Interestingly, f_v returned to normoxic values at the lowest DO₂ tested (0.57 mg/L). Following reoxygenation, f_v increased significantly to 154 min⁻¹. Significant elevations in both glucose and lactate were observed under hypoxia, with plasma lactates reaching 65.9 ± 7.5 µmol·mL⁻¹, >42 fold higher than normoxic levels.

f_h and f_v under simulated natural conditions

Under laboratory pond conditions, DO_2 increased rapidly following sunrise before declining again after sundown to a minimum at 06:00 hrs. f_h for *G. gibbiceps* was about 90 min^{-1} during normoxia ($n = 8$). f_h was highest just before sunrise when DO_2 levels were minimal and the animals were most active. f_v increased significantly as DO_2 fell, peaking earlier than f_h at 01:00 hrs. f_v declined at 06:00 hrs when DO_2 in the pond was minimal, corresponding with an increase in the amount of observed air breathing events. Plasma glucose levels following hypoxia were significantly elevated over oxygenated levels (29.84 ± 3.01 vs. $16.88 \pm 2.44 \mu\text{mol}\cdot\text{mL}^{-1}$, $n = 5$). Plasma lactate was also significantly elevated following hypoxia (7.18 ± 2.44 vs. $5.89 \pm 1.76 \mu\text{mol}\cdot\text{mL}^{-1}$ during oxygenation). Plasma glucose in fish held under oxygenated conditions in the pond was nearly 2 fold lower than those for fish held under normoxia in the laboratory ($p < 0.01$).

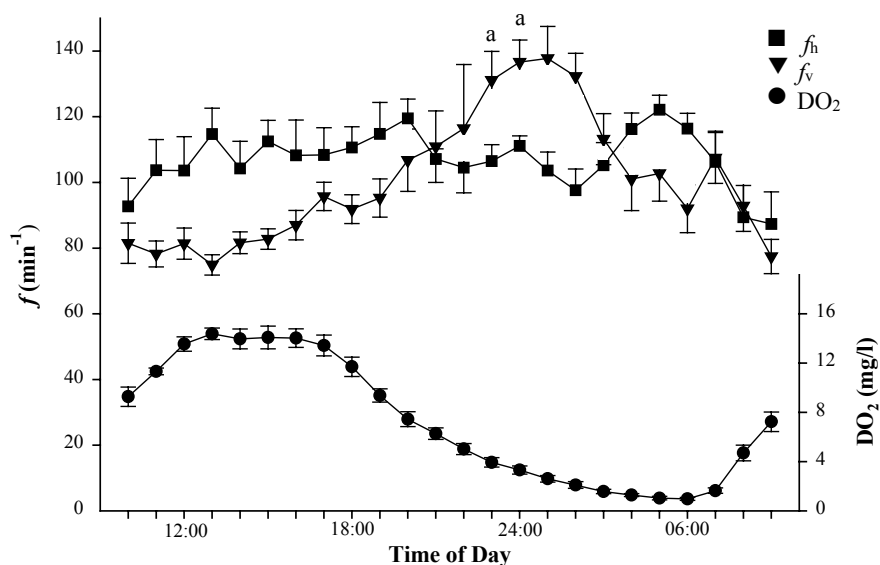
Figure 1. f_h and f_v for the armoured catfish *G. gibbiceps* denied aerial respiration and subjected to hypoxia and reoxygenation at 28°C under laboratory conditions ($n = 6$). a - significant difference from values at normoxia (DO_2 7.03 mg/L), b - significant difference from values at DO_2 0.57 mg/L ($P < 0.05$).



Radiotelemetry field studies

Fish exhibited a cyclical pattern of behaviour over the 52 hr sampling period. Animals remained on the bottom during the midday period and explored the upper water column more during the night and early morning (data not shown). This pattern of behaviour was identical to that observed in laboratory pond experiments, despite the high DO₂ levels in the field cages throughout the observation period.

Figure 2. Water DO₂ and associated f_h and f_v over 24 hrs for *G. gibbiceps* held in a laboratory pond (n = 8). Fish were allowed free access to the surface for aerial respiration. Temperature fluctuated between 28.4 and 35.1°C during the sampling period. a - significant difference from value at 10:00 hrs (P < 0.05).



Discussion

G. gibbiceps exhibited substantial tolerance to fluctuations in DO₂ under all conditions tested. The lack of a significant hypoxic bradycardia in *G. gibbiceps* is consistent with previous observations on *L. pardalis*. Though this is

uncharacteristic of a highly hypoxia tolerant fish, *G. gibbiceps* seems to have a remarkable ability to up-regulate anaerobic metabolism, as indicated by the extreme levels of plasma lactate under hypoxia. Elevations in anaerobic metabolism are likely maintained by high plasma glucose levels, supporting the theory that exogenous glucose is an important fuel in fish hearts during hypoxia (Driedzic and Bailey, 1999). Cardiac energy demand in armoured catfishes may also be reduced via activation of ATP-sensitive K⁺ channels (MacCormack et al., submitted), further compensating for the lack of a bradycardia. Our findings indicate that *G. gibbiceps* tolerates hypoxia by first increasing f_v and aerial respiration, followed by a strong activation of anaerobic metabolism.

Acknowledgements

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