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Gills and air-breathing organ in O2 uptake, CO2 excretion, N-waste excretion, and ionoregulation in small and large pirarucu (Arapaima gigas)

Bernd Pelster[1,2], Chris M. Wood[3,4], Susana Braz-Mota[5], Adalberto L. Val[5]
[1]Institute of Zoology, University of Innsbruck, Austria
[2]Center for Molecular Biosciences, University of Innsbruck, Austria
[3]Department of Zoology, University of British Columbia, Vancouver, Canada
[4]Department of Biology, McMaster University, Hamilton, Canada
[5]Laboratory of Ecophysiology and Molecular Evolution, Brazilian National Institute for Research of the Amazon, Manaus, Brazil

Abstract:

In the pirarucu (*Arapaima gigas*), gill surface area and thus gas exchange capacity of the gills are reduced with proceeding development. It, therefore, is expected that *A. gigas*, starting as a water breather, progressively turns into an obligate air-breathing fish using an air-breathing organ (ABO) for gas exchange. We assessed the air-breathing activity, O_2 and CO_2 exchange into air and water, ammonia-N and urea-N excretion, ion flux rates, and activities of ion transport ATPases in large versus small pirarucu. We found that even very young *A. gigas* (4–6 g, 2–3 weeks post-hatch) with extensive gills are airbreathers (18.1 breaths*h^{-1}) and cover most (63%) of their O_2 requirements from the air whereas 600–700-g animals (about 3–4 months post-hatch), with reduced gills, obtain 75% of their O_2 from the air (10.8 breaths*h^{-1}). Accordingly, the reduction in gill surface area hardly affected O_2 uptake, but development had a significant effect on aerial CO_2 excretion, which was very low (3%) in small fish and increased to 12% in larger fish, yielding a hyper-allometric scaling coefficient (1.12) in contrast to 0.82–0.84 for aquatic and total CO_2 excretion. Mass-specific ammonia excretion decreased in approximate proportion to mass-specific O_2 consumption as the fish grew, but urea-N excretion dropped from 18% (at 4–6 g) to 8% (at 600–700 g) of total N-excretion; scaling coefficients for all these parameters were 0.70–0.80. Mass-specific sodium influx and efflux rates, as well as potassium net loss rates, departed from this pattern, being greater in larger fish; hyper-allometric scaling coefficients were > 1.0. Gill V-type H^+ ATPase activities were greater than Na^+, K^+-ATPase activities, but levels were generally low and comparable in large and small fish, and similar activities were detected in the ABO. *A. gigas* is a carnivorous fish throughout its lifecycle, and, despite fasting, protein oxidation accounted for the major portion (61–82%) of aerobic metabolism in both large and small animals. ABO PO_2 and PCO_2 (measured in 600–700-g fish) were quite variable, and aerial hypoxia resulted in lower ABO PO_2 values. Under normoxic conditions, a positive correlation between breath volume and ABP PO_2 was detected, and on average with a single breath more than 50% of the ABO volume was exchanged. ABO PCO_2 values were in the range of 1.95–3.89 kPa, close to previously recorded blood PCO_2 levels. Aerial hypoxia (PO_2 down to 12.65 kPa) did not increase either air-breathing frequency or breath volume.

Keywords: air-breathing fish, gas exchange, teleost, ion regulation, nitrogen excretion