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Metabolic scope, swimming performance and the effects of hypoxia in the mulloway, *Argyrosomus japonicus* (Pisces: Sciaenidae)

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Abstract

The culture of the mulloway (*Argyrosomus japonicus*), like many other Sciaenidae fishes, is rapidly growing. However there is no information on their metabolic physiology. In this study, the effects of various hypoxia levels on the swimming performance and metabolic scope of juvenile mulloway (0.34±0.01 kg, mean±SE, n=30) was investigated (water temperature=22 °C). In normoxic conditions (dissolved oxygen=6.85 mg l^{-1}), mulloway oxygen consumption rate ($\dot{M}O_2$) increased exponentially with swimming speed to a maximum velocity (U_{crit}) of 1.7±<0.1 body lengths s^{-1} (BL s^{-1}) (n=6). Mulloway standard metabolic rate (SMR) was typical for non-tuna fishes (73±8 mg kg^{-1} h^{-1}) and they had a moderate scope for aerobic metabolism (5 times the SMR). Mulloway minimum gross cost of transport ($GCOT_{min}$, 0.14±0.01 mg kg^{-1} m^{-1}) and optimum swimming velocity (U_{opt}, 1.3±0.2 BL s^{-1}) were comparable to many other body and caudal fin swimming fish species. Energy expenditure was minimum when swimming between 0.3 and 0.5 BL s^{-1}. The critical dissolved oxygen level was 1.80 mg l^{-1} for mulloway swimming at 0.9 BL s^{-1}. This reveals that mulloway are well adapted to hypoxia, which is probably adaptive from their natural early life history within estuaries. In all levels of hypoxia (75% saturation=5.23, 50%=3.64, and 25%=1 .86 mg l^{-1}), $\dot{M}O_2$ increased linearly with swimming speed and active metabolic rate (AMR) was reduced (218±17, 202±14 and 175±10 mg kg^{-1} h^{-1} for 75%, 50% and 25% saturation respectively). However, U_{crit} was only reduced at 50% and 25% saturation (1.4±<0.1 and 1.4±<0.1 BL s^{-1} respectively). This demonstrates that although the metabolic capacity of mulloway is reduced in mild hypoxia (75% saturation) they are able to compensate to maintain swimming performance. $GCOT_{min}$ (0.09±0.01 mg kg^{-1} m^{-1}) and U_{opt} (0.8±0.1 BL s^{-1}) were significantly reduced at 25% dissolved oxygen saturation. As mulloway metabolic scope was significantly reduced at all hypoxia levels, it suggests that even mild hypoxia may reduce growth productivity.

Keywords: Mulloway; *Argyrosomus japonicus*; Sciaenidae; Metabolic scope; Hypoxia; Swimming performance; Standard metabolic rate; Active metabolic rate

1. Introduction

The mulloway (*Argyrosomus japonicus*, formerly *A. hololepidotus*) is a large sciaenid (maximum size 75 kg) that has recently become an aquaculture species

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(Battaglene and Talbot, 1994; Fielder and Bardsley, 1999; Hecht and Mperdempes, 2001). The mulloway is naturally distributed in the coastal waters of the Indian and eastern Pacific oceans and has long been an important commercial and recreational fisheries species in Australia and South Africa (Griffiths, 1997a; Griffiths and Heemstra, 1995). Juvenile mulloway reside in estuaries, whilst adults move close offshore and to surrounding surf zones (Gray and McDonal, 1993; Griffiths, 1996; 1997a,b). Attributes that make mulloway suitable for aquaculture include their high price, marketability, high fecundity, fast growth, non-territorial or cannibalistic nature, and saline resilience. These make mulloway suitable for both marine cage and on-land saline pond culture.

There is no metabolic information on the mulloway and little on other Sciaenidae fishes. This is despite sciaenid species becoming increasingly important to aquaculture world wide (Drawbridge, 2001; Holt, 2001; Thomas et al., 1996). In fact, sciaenid fishes are now the major fish species for artificial propagation in the world's leading producer of aquaculture products, China (Hong and Zhang, 2003). Consequently, there is a lack of precise metabolic data for calculations of aquaculture system oxygen requirements, fish energy requirements, environmental impact assessments and species-specific physiological thresholds.

Metabolism is the physiological engine that powers all activities such as swimming, growth and reproduction (Neill et al., 1994). The potential power that this engine can generate is determined by the aerobic metabolic scope, the difference between metabolic rate at the maximum sustained swimming speed (active metabolic rate, AMR) and the fish's minimum metabolic rate (standard metabolic rate, SMR). The greater the aerobic scope, the greater the potential for growth (Fry, 1971). Maintaining culture conditions for optimum metabolic scope will result in optimum potential productivity. For this reason, metabolic scope is considered to be an integral measure of environmental quality for aquaculture (Neill and Bryan, 1991). The environment influences the activity of an organism through its metabolism. Dissolved oxygen is considered to be a limiting factor, setting the upper limit of aerobic metabolism thus defining the metabolic scope (Fry, 1971). A decrease of dissolved oxygen results in the reduction of metabolic scope in fish (Claireaux et al., 2000; Fry, 1971; Jordan and Steffensen, 2007). Although the effects of reduced dissolved oxygen may not be acutely apparent, prolonged exposure can result in reduced growth performance (Priede, 1985).

The following study aims to define some of the metabolic parameters of the mulloway and considers how these interact with intensive aquaculture conditions. In particular, we examine the relationship between swimming velocity and metabolic rate ($\dot{M}O_2$) and determine the cost of transport (COT), SMR, AMR, metabolic scope, and critical swimming velocity (U_{crit}). Furthermore, we examine the effects of hypoxia on these parameters with the purpose of determining not just the minimum oxygen requirements, but also the potential production-limiting effects of hypoxia through modulation of the metabolic scope.

2. Materials and methods

2.1. Experimental animals

Thirty juvenile mulloway (0.34±0.08 kg, Table 1) were randomly selected from a 10,000 l, flow-through (3 mm gravel filtered seawater) stock tanks at the South Australian Research and Development Institute, Aquatic Sciences, West Beach facility. These fish had been raised on-site from fertilized eggs supplied by Clean Sea Pty. Ltd., commercial marine finfish hatchery (Spencer Gulf, South Australia). Fish were maintained at ambient light and water temperature. All experimental trials were conducted between December 2004 and March 2005 when ambient water temperatures remained between 21 and 23 °C. Fish were fed commercial marine diet (Nova, Skretting, Hobart, Australia) to satiation once a day but were starved for a minimum of 36 h before the beginning of all experimental trials.

For each trial, individual fish were scoop-netted from the stock tank and immediately transferred into a 2000 l fish transport container filled with seawater and carried 13 km to the University of Adelaide campus where all respiratory trials were conducted. Seawater from the transport container was used to gravity fill the respirometer, and the fish was introduced. All fish were introduced into the respirometer late in the afternoon and then left overnight to acclimate for a minimum of 16 h. During the

Table 1
Fish mass (M_b) and body length (BL), trial start point dissolved oxygen (DO), swim velocity range (U) achieved by mulloway swimming at 22 °C at progressively greater velocities and in the routine critical dissolved oxygen level experiment (R_{crit})

	M_b (kg)	BL (cm)	DO (mg l^{-1})	U (cm s^{-1})
100%	0.39±0.02	31.5±0.5	6.85±0.02	7.5–60.0
75%	0.34±0.01	32.0±0.3	5.23±0.02	7.5–52.5
50%	0.36±0.03	32.4±0.9	3.64±0.02	7.5–52.5
25%	0.33±0.01	31.6±0.4	1.86±0.02	7.5–45.0
R_{crit}	0.36±0.01	32.1±0.4	3.60–0.73	30.0

Values are means±SE, n=6 for M_b and BL, n=47–36 for DO.