Research Article

Oxygen Uptake In Relation To Sex And Different Phases Of Breeding Cycle In Channa Gachua (Ham.)

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Abstract

The nutrients release energy during the metabolic process of oxidation. The energy is used, on priority basis, for maintenance of life process; growth and other functions use surplus energy. Respiration and metabolic demands in fishes are profoundly influenced by reproductive physiology, environmental rhythms, and sex-specific behaviors. Channa gachua (Ham.) is a small air-breathing freshwater teleost in the family Channidae. Its respiration involves both aquatic and aerial oxygen uptake due to specialized accessory respiratory organs. The species also undergoes cyclic gonadal changes through discrete reproductive phases resting, preparatory, pre-spawning, spawning, and post-spawning, which modulate its physiological demands.Oxygen uptake and equivalent energy utilization (E.E.U.) in relation to sex and different phases of breeding cycle was studied in the adult air-breathing murrel fish, Channa gachua (Ham.). The values were higher in males (3.221 ml/h) as compared to females (2.715 ml/h). For different breeding phases, the values were minimum in resting phase (1.1473 ml/h) and followed in increasing order by postspawning (3.2708 ml/h), preparatory (3.4963 ml/h), spawning (5.3295 ml/h) and prespawning (5.5905 ml/h) periods. Understanding oxygen uptake in relation to these reproductive stages and sex differences is vital for advancing physiological ecology, aquaculture management, and conservation of this species.

Keywords: Oxygen uptake, equivalent energy utilization (EEU), Channa gachua, breeding cycle.

Introduction

Energy intake is a basic nutritional requirement in animals. The nutrients release energy during the metabolic process of oxidation. The energy is used, on priority basis, for maintenance of life process; growth and other functions use surplus energy. Lipids are the main source of metabolic energy to breeding (Tamira et al, 2017), provide essential fatty acids, and are important components of membrane (Tocher, 2003) and cell signaling involved in steroidogenesis (Mercure and Van Der Kraak, 1996).

The structural modifications and adaptations of air-breathing fishes have been investigated by many zoologists. (A K Patra et al 1983, Das 1927, 1933, 1935, 1940, Carter & Beadle 1931, Schottle 1931, Hora 1935, Marlier 1938, Nawar 1955, Munshi 1961, 1962). Gas exchange and respiratory patterns of some Indian air-breathing fishes such as Anabas testudineus, Heteropneustes fossilis, Clarias batrachus, Channa gachua and Trichogaster fasciatus have been studied by Hughes and Singh (1970a, b, 1971), Singh and Hughes (1971, 1973), Hakim et al.(1978, 1983), Ojha et al.(1977), Munshi et al.(1977) and Ojha and Dandotia (1978). A K Patra et al (1983) has described about their details. In the last years, a lot of attention has been given to the effects of fish diets on breeding (Coldebella et al., 2011; Pandey, A., 2024; Rumki, S.P. et al, 2024; Izquierdo, M. S., et al. 2001, Bera, P. et. al., 2025; Ahmadifar, E. et al.2025) and about the quantitative and qualitative production of the offspring (Parra et al., 2010; Mechaly, A. S.,et al, 2025; Yoneda, M.,et al 2025). However, the nutritional, and thus energy, requirements for Channa gachua broodstock have not yet been defined properly.

Early bioenergetic submodels of consumption and respiration assumed that males and females have comparable physiology (Kitchell et al.1977). The potential gender differences in these submodels have not been evaluated. Some published accounts show that standard metabolism and assimilation efficiencies can differ between males and females (Shillington 2005; Valle et al.2005). But sufficient data are currently lacking to parameterize accurately gender-based submodels for consumption and metabolism in percids (Michael D. Rennie et al 2008).

Currently, the formulation of diets for animals has been performed to meet energy requirements. The knowledge of the energy metabolism of fish is an indispensable tool for the preparation of suitable artificial diets (Tamira et al, 2017) for different sexes of a species and during the different phases of breeding cycle. It is still necessary to establish the most appropriate amount of energy.

Thus, the present study was conducted to evaluate the oxygen consumption in different sexes (male and female) and in the different phases of breeding cycle of Channa gachua (Ham.).

Material And Methods

Channa gachua is an air breathing freshwater snake-headed murrel fish. It belongs to the family Channidae of the order Anabantiformes (FishBase, 2025, after ECoF, Eschmeyer's Catalog of Fishes, 2024). Channidae was often included under order Perciformes, and also elevated to the level of an order, Channiformes. Due to its good flavour and no intermuscular spines, it is popular as food, especially among weaker sections of the society. To some extent, it is also used as an aquarium fish. It extracts O_2 from water through gills and from air by accessory respiratory organs - the suprabranchial chambers.

Live specimens of Channa gachua of almost the same body weight were procured from local fish dealer at Bodh-Gaya and kept in glass aquaria for a week for acclimatization. In the laboratory, they were fed daily with pieces of goat liver.

Oxygen consumption was measured in a closed glass respirometer. The fish had free access to air through a small semicircular hole (10 cm diameter) in a disc float. Carbosorb (B.D.H) or KOH in a Petri dish was placed on the float to absorb CO_2. The air phase of respirometer was connected to a differential manometer. The concentration of dissolved oxygen in the water was estimated by Winkler's volumetric method (Welch 1948). Oxygen uptake from air was measured and calculated by volume change in the manometer and by use of the combined gas law equations and vapour pressure (Dejours 1975). The respiratory chambers were immersed in a water bath to maintain a constant temperature.

Equivalent energy utilization (EEU) was estimated by applying an oxycaloric equivalent of 4.8 Kcal/litre of oxygen (Winberg, 1956)

Observations

The data showing the oxygen uptake and EEU in relation to sex and different phases of breeding cycle in this fish are summarized in Table 1 and 2 respectively. The breeding cycle of this fish has been divided into five phases – resting, preparatory, prespawning, spawning and postspawning.

Table 1: Oxygen uptake and equivalent energy utilization (EEU) in relation to sex in Channa gachua (Ham.). Body weight: 46 ± 1.5g; N = 6; Water temperature = 29 ± 1° C

S. No.	Sex	Oxygen uptake (ml/h)	Oxygen uptake (ml/kg/h)	Equivalent energy utilization (EEU)		
				Kcal/h	Kcal/d	Kcal/month
1	Male	3.221	70.022	0.0154	0.3710	11.1317
2	Female	2.715	59.022	0.0130	0.3127	9.3830

Table 2: Oxygen uptake and equivalent energy utilization (EEU) during different phases of breeding cycle in Channa gachua (Ham.). Body weight: 45 ± 1.5g; N = 6

S. No.	Period of breeding cycle	Oxygen uptake (ml/h)	Oxygen uptake (ml/kg/h)	Equivalent energy utilization (EEU)		
				Kcal/h	Kcal/d	Kcal/month
1	Preparatory	3.4963	77.6956	0.0168	0.4028	12.0832
2	Prespawning	5.5905	124.2333	0.0268	0.6440	19.3208
3	Spawning	5.3295	118.4333	0.0256	0.6140	18.4188
4	Postspawning	3.2708	72.6844	0.0157	0.3768	11.3039
5	Resting	1.1473	25.4956	0.0055	0.1322	3.9651

A perusal of the tables shows that

1. The oxygen uptake and equivalent energy utilization (EEU) were higher in males as compared to females, and
2. The oxygen uptake and equivalent energy utilization (EEU) were minimum in resting phase and followed in increasing order by postspawning, preparatory, spawning and prespawning periods.

Discussion

Respiration is one of the most important physiological parameters on which many of the vital functions like growth and reproduction of fishes depend (Holden 1973). In general, the maintenance energy requirement of fish is <10% of the maintenance energy required by birds or mammals (Smith 1989). Reasons may be diverse bur is partly due to the poikilothermic nature of fish.

Fish also exert less energy on posture and excretion (NRC 1983). Posture is assisted by buoyancy of the water. Fishes are ammonotelic and ammonia requires less energy than urea or uric acid for its disposal.

In present work, Channa gachua shows differences in the oxygen consumption in different sexes. Oxygen consumption, and thus energy utilization, in male Channa gachua has been found higher than in female. The gender differences in either energy allocation or acquisition have been observed in the animal kingdom (fish: Roff 1983; Holtby & Healey 1990; Henderson et al 2003). Such differential energy is needed for sexual size dimorphism (SSD) and sex-specific reproductive behavior (Michael D. Rennie et al 2008). Fishes as a taxonomic group (e.g. Hickman et al) show a wide array of different sex-dependent reproductive allocation of energy and matter.

Female fish shows relatively high energy investment in gonad production as compared to males (e.g. Henderson, Wong & Nepszy 1996). However, energy allocation to gonads is only one aspect of reproduction, which is simple to measure and has therefore received much attention. More difficult to quantify are other 'costly' behaviours which may be related to reproduction, such as activity related to finding and competing for mates and/or reduced feeding during mating (Michael D. Rennie, 2008).

Growth rates of both sexes are similar in young fish of certain species, but sexual size dimorphism (SSD) exists in older individuals (Michael D. Rennie et al 2008). The comparatively cheap gametes of the male commonly leads to the situation where males are the sex in surplus, since any given male may produce enough sperm to fertilize the offspring from a number of females (but examples are available on sex role reversal). In order to increase the number of potential spawns and thus the reproductive success of any male, they regularly invest energy and matter into sexual characteristics- secondary sexual character (and breeding behavioral activities). This illustrates the possible difference between female and male energy budgets, as females usually invest considerable energy resources into gonads, whereas males invest more into secondary sexual characters and reproductive behavior (Ole Kristian Berg et al 2008). Thus, a greater net loss of energy due to reproductive activity partly explains the greater requirement of energy in mature males. However, further investigations are required into the dependence of bioenergetic and contaminant allometries on gender.

Oxygen uptake and equivalent energy utilization (EEU) in different phases of breeding cycle of Channa gachua has also been estimated in present work. The breeding cycle of Channa gachua has been divided into five phases – resting, preparatory, prespawning, spawning and postspawning. The oxygen uptake and equivalent energy utilization (EEU) were found minimum in resting phase and followed in increasing order by postspawning, preparatory, spawning and prespawning periods.

Reproduction has energetic and physiological costs. A central assumption of life-history theory is the existence in iteroparous organisms of a trade-off between present reproduction and future reproductive output, this being the consequence of an ultimate trade-off among survival, growth and reproduction (Roff, 1992; Stearns, 1992). Species that reproduce only once (semelparous) invest most of their energy in reproduction before dying. Consequently, the energetic costs of reproduction and the facility to restore energy after each reproductive event influence both mortality and the ability to spawn in future year.

The energy acquired by fish through feeding is used for reproduction, metabolism, and growth, or is accumulated in the form of energy reserves (Jobling, 1994). In general, immature individuals exhibited lower concentrations of muscular energy and body cavity fat. In juveniles, most of the energy is allocated to metabolism and somatic production, leaving low levels of energy in their bodies (Tytler & Calow, 1985). Conversely, adults store large amounts of energy to support reproductive processes (Wootton, 1985). According to Zwolinski et al. (2001), significant amounts of body cavity fat are used by fish to supply the high energy cost required for gonadal development. There is a direct flow of energy from its body cavity fat reserves to the gonads. The highest energy content among primary female reproductive organs is found in gonads with oocytes already in the process of vitellogenesis (Rodrigo et al. 2010). This explains, perhaps partly, the highest energy consumption during prespawning periods in females. Spawning activities also warrant energy which is responsible for high oxygen uptake during spawning phase of the breeding cycle. In addition to the investment into the pre-zygotic egg, the behavioural investment in post-zygotic protection and parental care (Clutton-Brock, 1991; Mousseau and Fox, 1998; Wilson et al. 2003) can represent increased energy investment into reproduction. The parent investment is increased by the involvement of parental care as guarders and bearers of eggs or other mechanisms. Channa gachua is a mouth brooder. Both sexes are involved in parental care activities. This may account for greater energy needs, and hence greater oxygen uptake, in postspawning parents than in resting phase individuals.

The most frequently discussed problem of energy partitioning in poikilothermic animals has been the trade-off between somatic and reproductive growth (Townsend & Calow, 1981). A poikilothermic animal may very well be able to defray at least part of the costs of reproduction by saving on the energy demand of locomotion and less important activities. Such energy partioning has not been discussed here; it needs further investigation.

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References

1. Ahmadifar, E., Fallah, H. P., Chandran, D., Mohammadzadeh, S., Dehghani, M., Guerreiro, I., & Abdel-Latif, H. M. (2025). Botanical interventions for controlling reproduction in fish–an overview. Annals of Animal Science, (3), 921-928.
2. Bera, P., Dhara, H., Mandal, S., Sau, S. K., & Das, S. (2025). Nutritional strategies for improving reproductive performance in fishes. In Aquaculture: Enhancing food security and nutrition (pp. 409-430). Springer Nature Switzerland.
3. Berg, O. K., & Finstad, A. G. (2008). Energetic trade–offs in reproduction: Cost–benefit considerations and plasticity. In M. J. Rocha, A. Arukwe, & B. G. Kapoor (Eds.), Fish reproduction. CRC Press.
4. Clutton-Brock, T. H. (1991). The evolution of parental care. Princeton University Press.
5. Coldebella, I. J., Radünz-Neto, J., Mallmann, C. A., Veiverberg, C. A., Bergamin, G. T., Pedron, F. A., Ferreira, D., & Barcellos, L. J. G. (2011). The effects of different protein levels in the diet on reproductive indexes of Rhamdia quelen females. Aquaculture, 312(1-4), 137-144. doi.org
6. Dejours, P. (1975). Principles of comparative respiratory physiology. North-Holland Publishing Co.
7. dos Santos, R. N., Amadio, S., & Ferreira, E. J. G. (2010). Patterns of energy allocation to reproduction in three Amazonian fish species. Neotropical Ichthyology, 8(1), 177–185. doi.org
8. Fricke, R., Eschmeyer, W. N., & Van der Laan, R. (Eds.). (2025, December). Eschmeyer's catalog of fishes: Genera, species, references. California Academy of Sciences. calacademy.org
9. Froese, R., & Pauly, D. (Eds.). (2025, December). FishBase (Version 04/2025). fishbase.org
10. Henderson, B. A., Collins, N., Morgan, G. E., & Vaillancourt, A. (2003). Sexual size dimorphism of walleye (Stizostedion vitreum vitreum). Canadian Journal of Fisheries and Aquatic Sciences, 60(11), 1345–1352. doi.org
11. Henderson, B. A., Wong, J. L., & Nepszy, S. J. (1996). Reproduction of walleye in Lake Erie: Allocation of energy. Canadian Journal of Fisheries and Aquatic Sciences, 53(1), 127–133. doi.org
12. Hickman, C. P., Roberts, L. S., Larson, A., & I'Anson, H. (2004). Integrated principles of zoology. McGraw-Hill.
13. Holden, A. V. (1973). The effects of pesticides on life in freshwater. Proceedings of the Royal Society of London. Series B. Biological Sciences, 180(1061), 383-394. doi.org
14. Holtby, L. B., & Healey, M. C. (1990). Sex-specific life-history tactics and risk-taking in coho salmon. Ecology, 71(2), 678–690. doi.org
15. Izquierdo, M. S., Fernandez-Palacios, H., & Tacon, A. G. J. (2001). Effect of broodstock nutrition on reproductive performance of fish. Aquaculture, 197(1-4), 25-42. doi.org
16. Jobling, M. (1994). Fish bioenergetics. Chapman and Hall.
17. Jobling, M. (1995). Environmental biology of fishes. Chapman and Hall.
18. Kitchell, J. F., Stewart, D. J., & Weininger, D. (1977). Applications of a bioenergetics model to yellow perch (Perca flavescens) and walleye (Stizostedion vitreum vitreum). Journal of the Fisheries Research Board of Canada, 34(10), 1922–1935. doi.org
19. Mechaly, A. S., Awruch, C., Cabrita, E., Costas, B., Fernandes, J. M., Gallego, V., Hirt-Chabbert, J., Konstantinidis, I., Olivera, C., Ramos-Júdez, S., Ramos-Pinto, L., & Fatsini, E. (2025). Cutting-edge methods in teleost and chondrichthyan reproductive biology. Reviews in Fisheries Science & Aquaculture, 33(1), 77-112. doi.org
20. Mercure, F., & Van Der Kraak, G. (1996). Mechanisms of action of free arachidonic acid on ovarian steroid production in the goldfish. General and Comparative Endocrinology, 102(1), 130-140. doi.org
21. Mousseau, T. A., & Fox, C. (1998). The adaptive significance of maternal effects. Trends in Ecology & Evolution, 13(10), 403–407. doi.org
22. National Research Council. (1983). Nutritional requirement of warmwater fishes and shellfishes. National Academy Press.
23. Orlando, T. M., de Oliveira, M. M., Paulino, R. R., Costa, A. C., Allaman, I. B., & Rosa, P. V. (2017). Reproductive performance of female Nile tilapia (Oreochromis niloticus) fed diets with different digestible energy levels. Revista Brasileira de Zootecnia, 46(1), 1-7. doi.org
24. Pandey, A. (2024). Role of broodstock nutrition and its impacts on fish reproductive output: An overview. Agricultural Reviews, 45(4), 699-704. doi.org
25. Parra, J. E. G., Radünz-Neto, J., Veiverberg, C. A., Lazzari, R., Bergamin, G. T., Corrêia, V., Ferreira, C. C., & Ferreira, F. W. (2010). Desempenho reprodutivo de fêmeas de jundiá alimentadas com diferentes fontes protéicas. Archivos de Zootecnia, 59(226), 255-265. doi.org
26. Patra, A. K., Datta Munshi, J. S., & Hughes, G. M. (1983). Oxygen consumption of freshwater air-breathing Indian siluroid fish, Clarias batrachus (Linn.) in relation to body size and seasons. Proceedings of the Indian National Science Academy, B49(6), 566–574.

27. Rennie, M. D., Purchase, C. F., Lester, N., Collins, N. C., Shuter, B. J., & Abrams, P. A. (2008). Lazy males? Bioenergetic differences in energy acquisition and metabolism help to explain sexual size dimorphism in percids. Journal of Animal Ecology, 77(5), 916–926. doi.org
28. Roff, D. A. (1983). An allocation model of growth and reproduction in fish. Canadian Journal of Fisheries and Aquatic Sciences, 40(9), 1395–1404. doi.org
29. Rumki, S. P., Moniruzzaman, M., Hossain, M. S., Saha, T. K., Tabassum, A., Moin, M. B., Mondol, S. K., Ibnat, S., Bai, S. C., Min, T., & Hossain, Z. (2024). Effects of dietary polyunsaturated fatty acid enriched diets on breeding, embryonic development and organogenesis of Rohu carp, Labeo rohita (Hamilton 1822). Reproduction and Breeding, 4(3), 155-163. doi.org
30. Shillington, C. (2005). Inter-sexual differences in resting metabolic rates in the Texas tarantula, Aphonopelma anax. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 142(4), 439–445. doi.org
31. Smith, R. R. (1989). Nutritional energetics. In J. E. Halver (Ed.), Fish nutrition (2nd ed., pp. 1-30). Academic Press.
32. Stearns, S. C. (1992). The evolution of life histories. Oxford University Press.
33. Tocher, D. R. (2003). Metabolism and functions of lipids and fatty acids in teleost fish. Reviews in Fisheries Science, 11(2), 107-184. doi.org
34. Townsend, C. R., & Calow, P. (Eds.). (1981). Physiological ecology: An evolutionary approach to resource use. Blackwell Scientific Publications.
35. Tytler, P., & Calow, P. (1985). Fish energetics: New perspectives. Croom Helm.
36. Valle, A., Catala-Niell, A., Colom, B., Garcia-Palmer, F. J., Oliver, J., & Roca, P. (2005). Sex-related differences in energy balance in response to caloric restriction. American Journal of Physiology-Endocrinology and Metabolism, 289(1), E15–E22. doi.org
37. Welch, P. S. (1948). Limnological methods. McGraw Hill Book Co. Inc.
38. Wilson, A. B., Ahnesjo, I., Vincent, A. C. J., & Meyer, A. (2003). The dynamic of male brooding, mating patterns and sex roles in pipefishes and seahorses Family Syngnathidae. Evolution, 57(6), 1374-1386. doi.org
39. Winberg, G. G. (1956). Rate of metabolism and food requirements of fishes (Fisheries Research Board of Canada Translation Series No. 194). Fisheries Research Board of Canada.
40. Wootton, R. J. (1985). Energetics of reproduction. In P. Tytler & P. Calow (Eds.), Fish energetics: New perspectives (pp. 231-254). Croom Helm.
41. Wootton, R. J. (1998). Ecology of teleost fishes (Fish and Fisheries Series 24). Kluwer Academic Publishers.
42. Yoneda, M., Nakamura, M., Morioka, T., Tsuzaki, T., Togashi, H., & Yukami, R. (2025). Experimental evidence of a mixed breeding strategy and food-dependent maternal and larval traits in chub mackerel. Frontiers in Marine Science, 12, Article 1674359. doi.org.