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Dissolved Oxygen Environments of the Fish Farm in Yashima Bay, Japan II. Respiration of Globefish (*Takifugu rubripes*)

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ABSTRACT

The respiration rate or oxygen consumption of globefish (*Takifugu rubripes*) can be expressed as:

$$R(\theta) = 0.764 Q_{01}^{(\theta-20)} W^{0.71}$$

where $R_{(q)}$ = unfed and resting metabolism measured as weight of oxygen consumed per fish per hour (mgO_2/hr) at θ°C, Q_{01} = temperature coefficient for unfed and resting metabolism (1.076), W = fresh body weight in grams. The body weight exponent (δ) is expressed as the values of 0.71 whilst the level of metabolism at 20°C ($\alpha_{(20)}$) is 0.764. The respiration of globefish with average body weight 538 g, the value was 87 mgO_2/hr. Comparing to other fishes, the respiration rate of globefish was only 1.25% of total cultured fish in Yashima Bay.

Key words : respiration, oxygen consumption, globefish, body weight exponent, level of metabolism

INTRODUCTION

There are many factors which influence the respiratory rate of fish: the direct temperature, temperature acclimation, oxygen and carbon dioxide content of the water, body weight, body fat content, cruising speed or activity, amount of feeding or degree of starvation, extent of social facilitation, sex, sexual development and spawning, excitement, injury,shock, disease, parasitism and perhaps many factors (Wohlschlag and Juliano, 1959). However, the body weight and temperature are accounted for the most of the variability in respiratory rate.

Fish metabolism is usually equated to oxygen consumption, the assumption being that all energy is released aerobically. More precise estimates of metabolism can be obtained from simultaneous measurements of oxygen uptake and carbon dioxide production or calorific output (Beamish and Dickie, 1967). Fry (1957, 1971); Beamish (1964); Beamish and Dickie (1967) have concluded that the importance of activity in respiration studies is acknowledged by the definition of three generally recognized levels of oxygen consumption, each defined in relation to activity. A lower limit of oxygen consumption variously termed 'non-active', 'resting' or more commonly 'standard', may be taken as the oxygen consumed in the absence of measurable movement. The procedure for determination of standard oxygen consumption is the simultaneous measurement of spontaneous activity and oxygen consumption. Standard oxygen consumption can be derived by extrapolation of the

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relation, which is linear over the range of activities usually observed in a respiration chamber, to zero activity.

Oxygen consumption in the presence of spontaneous activity is termed 'routine'. Measurements are usually made on fish in moderate confinement with suitable precautions against external stimuli. An upper limit of oxygen consumption, termed 'active', is defined as the maximum rate of oxygen consumption under continuous forced activity.

The purpose of this experiment was to investigate the respiration rate or oxygen consumption rate of globefish (Fugu in japanese) in resting state as a function of body weight and temperature.

MATERIALS AND METHODS

The experiment was adopted in a closed system by using the rectangular respiration chamber volume 75.6 l which was sealed with a plastic lid having a hold fitted with a rubber stopper which a stirrer and an oxygen sensor were inserted. The fishes were introduced into the experimental chamber at least twelve hours before the experiment was begun. Customarily, the body temperature of the fish is increased by stimulation, the experimental chamber were covered with black plastic shields to prevent the external stimulus *eg.* movement and light.

The temperature of water was totally controlled, all the experiments were done at 20°C. Dissolved oxygen concentration in the respiration chamber were determined by the oxygen sensor (YSI Model 57) and recorded continuously by portable recorder (YEW Model 3087). The experimental fishes were not fed for the purpose of acclimation, so that the respiration values could be taken as a standard or resting metabolism. Due to space limitation within the chamber, individual fish was employed in each experiment. Fresh body weight of fish, water temperature and salinity were measured at the end of each experiment.

RESULTS AND DISCUSSION

The rate of oxygen consumption or respiration rate of globefish is calculated from the difference between the oxygen content at time t_1 and t_2 by the following equation:

$$R = \frac{dM_{(O_2)}}{dt} = \frac{V(Y_1 - Y_2)}{T_2 - T_1} \qquad (1)$$

where

R = the respiration rate (mgO_2/hr),
V = volume of respiration chamber (l),
Y_1 = DO concentration at time t_1 (mgO_2/l),
Y_2 = DO concentration at time t_2 (mgO_2/l).

In general, the relationship between the rate of metabolism of unfed and resting fishes derived from measurement of oxygen consumption and their body weights (Fry, 1957, 1971; Paloheimo and Dickie, 1965, 1966a, 1966b; Chindamaikul, 1985; Kruesanae, 1992) is described by the following equation:

$$R_{(\theta)} = \alpha_{(\theta)} W^{\delta} \qquad (2)$$

where

$R_{(\theta)}$ = unfed and resting metabolism measured as weight of oxygen consumed per fish per hour (mgO_2/hr),
W = fresh body weight in grams,
$\alpha_{(\theta)}$ = level of unfed and resting metabolism,
δ = body weight exponent for unfed and resting metabolism.

The dependence of the level of metabolism of unfed and resting fish on temperature is expressed by the equation:

$$\alpha_{(\theta)} = \alpha_{(20)} Q_{01}^{(\theta - 20)} \qquad (3)$$

where

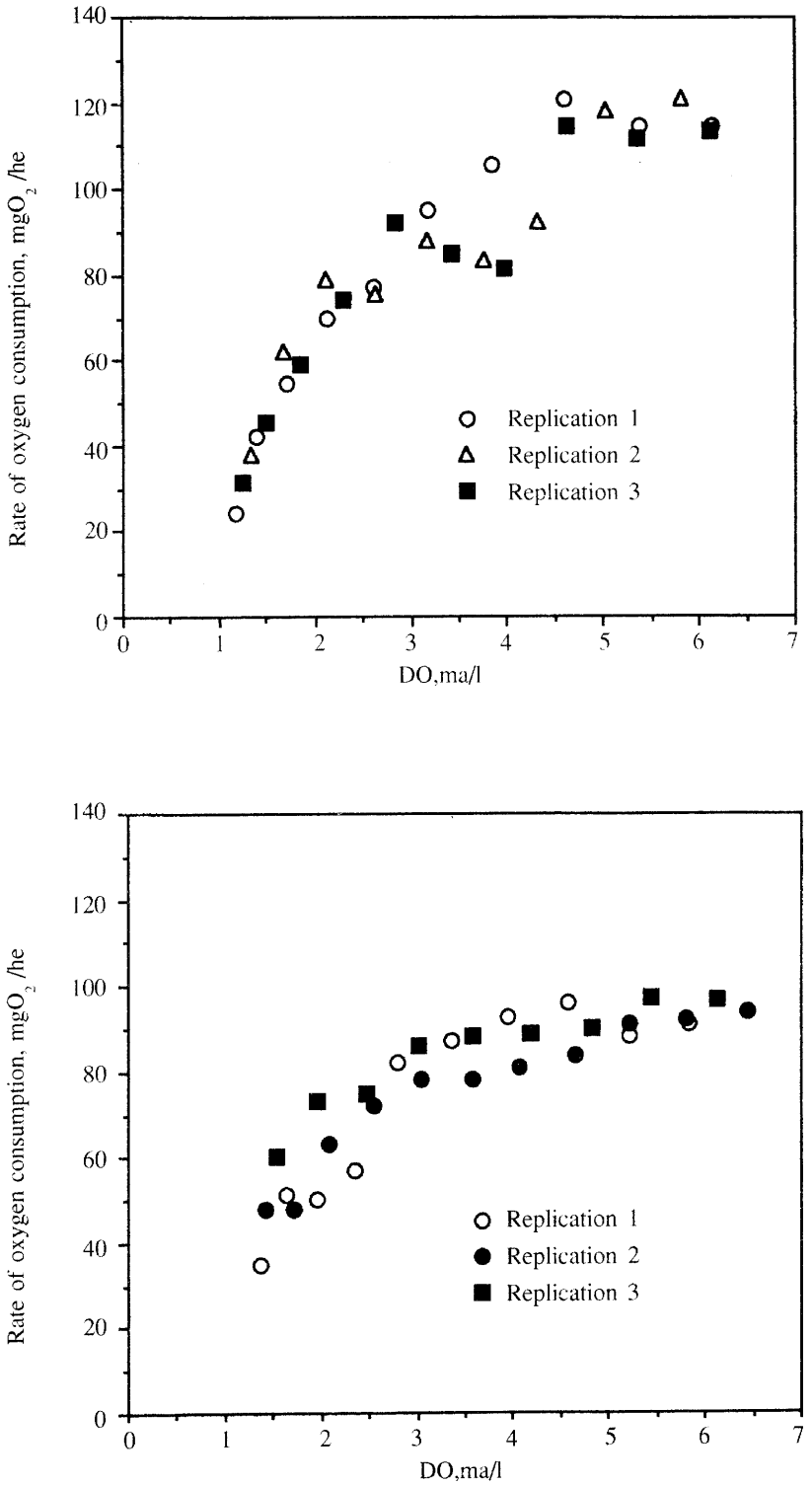


Figure 2 Oxygen consumption rate of globefish (mgO_2/hr) at temperature 20°C, body weight 0.87 kg.

$\alpha_{(\theta)}$ = level of unfed and resting metabolism at θ° C,

$\alpha_{(20)}$ = level of unfed and resting metabolism at 20°C,

Q_{01} = temperature coefficient for unfed and resting metabolism.

The oxygen consumption of globefish after acclimation in respiration chamber for 12 hr. (during that time fishes were not fed) is taken as a standard or resting metabolism. The metabolic rate of fish varied directly with body weight, water temperature, activity, and physiological condition of fish. In general, the resting metabolism is proportional to some power function of fresh body weight as given in equation (2). The respiration rate of globefish at different body weight was shown in Figure 1, 2 and 3, when body weight of globefish was increasing the higher respiration rate was presented. It is known that metabolic rate of fish in relation to size gives a straight line when the logarithm of the respiratory rate is plotted against the logarithm of the body weight (Fry, 1957; Wohlschlag and Juliano, 1959; Beamish and Dickie, 1967). The results showed that the slope value which expressed as a weight exponent, δ, was less than unity and could be assumed to a value of 0.71 (Figure 4).

Healey (1972) measured the respiration rate of 43 sand gobies (*Gobius minutus*), and found that the a value of sand goby was 0.62. He pointed out that the sand goby was a sedentary fish, therefore, routine metabolism of sand goby probably did not differ much from standard metabolism and most certainly represented metabolism at a low level of activity. Concordant with Edwards *et al.* (1969) observed on oxygen consumption of plaice and obtained the value of δ as 0.721 and Kruesanae (1992) found that the oxygen consumption of flounder gave a value of d as 0.72. Likewise, the observation in this study, the globefish usually rested on the bottom of the respiration chamber and showed very little movement during measurements so that the value obtained was close to the standard or resting metabolism.

As the experiment were conducted at the temperature of 20°C, the results depicted that the level of metabolism of globefish at 20°C gave the $\alpha_{(20)}$ as 0.764. By using the slope value of 0.71 and the temperature coefficient for metabolism (Q_{01}) from Kruesanae (1992) which defined as 1.076, therefore, the respiration rate of globefish could be expressed as:

$$R(\theta) = 0.764 Q_{01}^{(\theta-20)} W^{0.71} \qquad (4)$$

where

$R_{(\theta)}$ = unfed and resting metabolism measured as weight of oxygen consumed per fish per hour (mgO_2/hr) at θ°C,

Q_{01} = temperature coefficient for unfed and resting metabolism,

W = fresh body weight in gram.

Factors affecting estimation of the weight exponent

Paloheimo and Dickie (1966a) pointed out that the estimate of the exponent, δ, may be affected by complex interactions of metabolism and body size with temperature from season to season, or by adaptations to habitat temperature, they referred to many references which reported that the resting metabolism of fishes which collected and tested during winter condition showed a δ value of about 0.8. However, the same winter fish, when acclimated and tested in summer condition displayed low exponent. They concluded that temperature effect may play a determining role in the apparent value of the exponent.

Beamish (1964) reported the results of his work on several species acclimated to different temperatures with effects of spontaneous activity eliminated, and compared them with the results of other investigators. While there were some sugges-

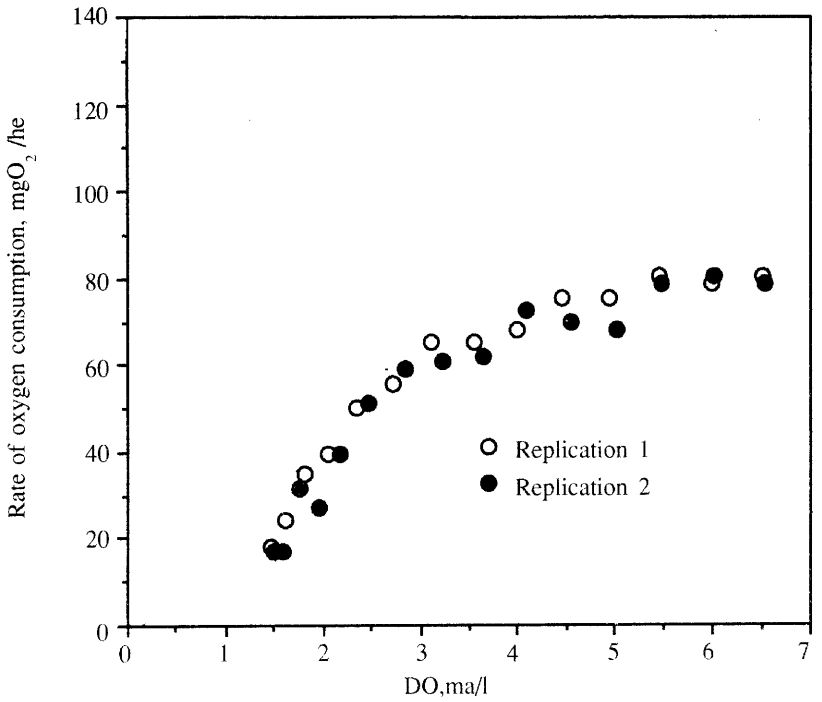


Figure 3 Oxygen consumption rate of globefish (mgO_2/hr) at temperature 20°C, body weight 0.65 kg.

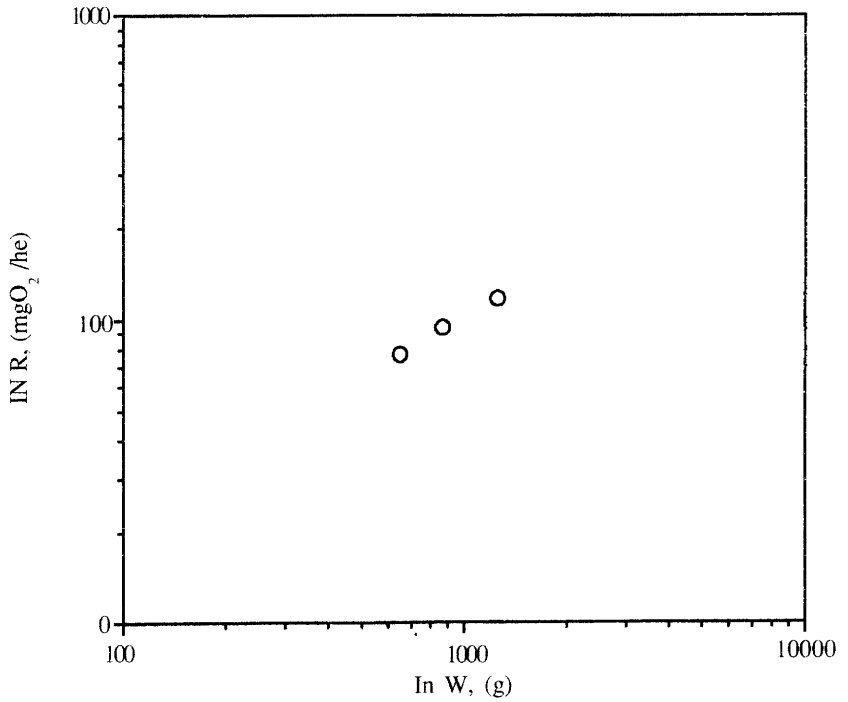


Figure 4 Relationship between In W and In R of globefish, the slope value which expressed as a weight exponent could be assumed to a value of 0.71

tive differences among species and temperatures in the exponent relating standard metabolism to body weight, few of these appeared to be statistically significant, and the influence of variations among individuals or due to small change in experimental design could not be eliminated. He concluded that the exponent for standard metabolism must be in the range of 0.8-0.9, and compared this with other recently reported values of resting or routine metabolism was about 0.7-0.9.

Thus, it can be concluded that work with oxygen consumption of fishes indicates stability of the exponential-type relationship between metabolism and body size at both standard and routine metabolism. A value for exponent δ of about 0.80 seems to provide an adequate general description for this relationship among a majority fishes under more or less constant and nonstress conditions.

Factors affecting the metabolic level

By contrast with the apparent stability of the exponent, the level of metabolism expressed by a appears to be markedly affected by changes in a variety of conditions. Paloheimo and Dickie (1965) found that at a particular level of food abundance and availability of a particular temperature, fish of different size appeared to adjust their various components of metabolism and feeding to more or less stable levels, resulting in a particular value of α. They concluded that different values of α resulted from a different food or temperature level, higher α resulted from higher levels of food availability, and temperature effects showed an elevation of α with increasing temperature. The results agreed well with Wealtherley (1972) and Inoue (1978), who pointed out that at higher temperature the level of metabolism of fish of various size seemed to increase. Furthermore, Kerr (1971) indicated that the level of total metabolism would be proportional to the assigned level of rations. However, it had been noted in addition that there were diurnal differences and effects of activity levels of α (Fry, 1957) as well as differences apparently associated with type of habitat. The observation especially suggested the possibility of adaptation of the level of metabolism to living conditions.

Respiration of cultured fishes in Yashima Bay

There are four kinds of fish cultured in Yashima Bay, yellowtail (Hamachi, *Seriola quinqueradiata* and Kampachi, *Seriola dumerili*), flounder (Hirame, *Paralichthys olivaceus*), and globefish (Fugu, *Takifugu rubripes*). Chindamaikul (1985) determined the resting metabolism rate of 1 year old yellowtail with average body weight 1069 g, the value was 327.9 mgO_2/hr and he proposed the equation to determined the dependence of the resting metabolism rate upon fresh body weight and temperature as:

$$R_{(\theta)} = 0.946 Q_{01}^{(\theta-20)} W^{0.749} \quad (6)$$

where

$R_{(\theta)}$ = unfed and resting metabolism measured as weight of oxygen consumed per fish per hour (mgO_2/hr) at θ°C,

Q_{01} = 1.126,

W = fresh body weight in gram.

Kruesanae (1992) studied in flounder (*Paralichthys olivaceus*), he obtained the slope value from the logarithm of the respiratory rate plotting against the logarithm of the body weight expressed as a weight exponent, d, and he assumed the value of δ as 0.72, the values of $\alpha_{(20)}$ as 0.410 and the temperature coefficient for metabolism (Q_{01}) was 1.076. He postulated the respiration equation for flounder as:

$$R_{(\theta)} = 0.410 Q_{01}^{(\theta-20)} W^{0.72} \quad (7)$$

To determine the respiration rate of yellowtail, Kampachi (*Seriola dumerili*), which is the same genus as Hamachi(*Seriola quinqueradiata*) thus, the equation (6) can be adopted. Knowing the

Table 1 Respiration of cultured fishes in Yashima Bay, observation on 3-4 September 1992 (studied area is 113.1×10^4 m^2).

Fishes	Average body weight (g)	Rate of respiration/fish (mgO_2/hr)	Number of fishes (ind)	Total respiration (gO_2/hr)	Oxygen consumption (gO_2/m^2.hr)
Yellowtail (*Seriola quinqueradiata*)	1870	467	371.1×10^3	173.4×10^3	0.1534
Yellowtail (*Seriola dumerili*)	1790	452	69.9×10^3	31.6×10^3	0.0279
Flounder (*Paralichthys olivaceus*)	495	50	23.4×10^3	1.2×10^3	0.0010
Globefish (*Takifugu rubripes*)	538	87	30.2×10^3	2.6×10^3	0.0023
Total				208.8×10^3	0.1846

number of fishes cultured in Yashima Bay and their body weight, the respiration rate can be determined by using equation (5), (6), and (7). The results are shown in Table 1. The respiration of globefish with average body weight 538 g, was 87 mgO_2/hr. Comparing to other fishes, the respiration of globefish was only 1.25% of total cultured fish whilst oxygen consumption of yellowtail was the majority of respiration of fishes cultured in this area. The differences of physiology, habitat and body weight of cultured fish in Yashima Bay make the difference in respiration rate. Flounder and globefish always stay calm on the bottom surface of net cage so that the respiration rate is quite low whilst yellowtail is always swimming in the water column thus, the respiration rate of yellowtail must be higher than bottom surface one.

LITERATURE CITED

Beamish, F. W. H. and L. M. Dickie. 1967. Metabolism and biological production in fish, pp. 215-242. *In* S. D. Derking (ed.), The Biological Basis of Fresh Water Fish Production. Blackwell Scientific Publications, Oxford.

Beamish, F. W. H. 1964. Respiration of fishes with special emphasis on standard oxygen consumption. II. Influence of weight and temperature on respiration of several species., Canadian Journal of Zoology. 42: 177-188.

Chindamaikul, T. 1985. Studies on energy, nitrogen and carbon budgets of the cultured yellowtails (*Seriola quinqueradiata*). M.S. Thesis of Kagawa Univ., Japan.

Edwards, R. R. C., D. M. Finlayson, and J. H. Steele. 1969. The ecology of O-group plaice and common dabs in Loch Ewe. II. Experimental studies of metabolism. J. Exp. Mar. Biol. Ecol. 3: 1-17.

Fry, F. E. J. 1957. The aquatic respiration of fish, pp. 1-63. *In* M. E. Brown (ed.), The Physiology

of Fishes. V. 1; Metabolism. Academic Press. New York.

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish, pp. 1-98. *In* W. S. Hoar and D. J. Randall (eds.), Fish Physio-logy. V. 6; Environmental relations and behavior. Academic Press. New York.

Healey, M. C. 1972. Bioenergetics of a sand goby (*Gobius minutus*) population. J. Fish. Res. Board Can. 29: 187-194.

Inoue, H. 1978. Effects of water temperature and body size on growth rate of juvenile yellowtail, *Seriola quinqueradiata*, cultured in Japan. Tech. Bull. of Fac. of Agri, Kagawa Univ. 29: 305-321.

Kerr, S.R. 1971. Analysis of laboratory experiments on growth efficiency of fishes. J. Fish. Res. Board Can. 28 : 801-808.

Kruesanae, V. 1992. Ecological bioenergetics in the cultured flounder (*Paralichthys olivaceus*). M.S. Thesis of Kagawa Univ., Japan.

Paloheimo, J. E. and L. M. Dickie. 1965. Food and growth of fishes. I. A growth curve derived from experimental data. J. Fish. Res. Board. Can. 22: 521-542.

Paloheimo, J. E. and L. M. Dickie. 1966(a). Food and growth of fishes. II. Effects of food and temperature on the relation between metabolism and body size. J. Fish. Res. Board Can. 23: 869-908.

Paloheimo, J. E. and L. M. Dickie. 1966(b). Food and growth of fishes. III. Relations among food, body size, and growth efficiency. J. Fish. Res. Board Can. 23: 1209-1248.

Weatherley, A. H. 1972. Growth and Ecology of Fish Populations. Academic Press, London. 293 p.

Wohlschlag, D. E. and R. O. Juliano. 1959. Seasonal changes in bluegill metabolism. Limnol. Oceanogr. 4: 195-209.