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## THE INFLUENCE OF TEMPERATURE AND WET WEIGHT ON THE OXYGEN DEMAND OF RAINBOW TROUT (*SALMO GAIRDNERI* R.) IN FRESH WATER

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### ABSTRACT

Muller-Feuga, A., Petit, J. and Sabaut, J.J., 1978. The influence of temperature and wet weight on the oxygen demand of rainbow trout (*Salmo gairdneri* R.) in fresh water. *Aquaculture*, 14: 355-363.

Multiple regression analysis was applied to a series of oxygen demand measurements on rainbow trout. It confirmed the determinant influence of temperature and size of fish under standard feeding conditions. Two types of adjustment of oxygen demand in relation to those two factors were tested, and one of them was chosen in which the temperature is under an exponential form. This allows the introduction of the  $Q_{10}$  concept. The value of  $Q_{10}$  is 3.5 when the water temperature is below 10°C and 1.7 above 12°C.

### INTRODUCTION

The water temperature has a determinant influence on the oxygen demand of fish, especially salmonids. Elliot (1969) found the oxygen demand related to the body weight of chinook salmon and to water-flow to be a linear function of temperature.

The influence of fish size was demonstrated, and Liao (1971) suggested an equation introducing that factor.

However, locomotory activity (Beamish and Dickie, 1967; Brett, 1973), salinity (Madan Mohan Rao, 1971), sex and breeding activity (Brett, 1973), and feeding level (Haskell, 1955; Willoughby 1968; Sparre, 1976) must also be considered. In fish farming, the first three of these factors are rather constant, and they play a lesser part than temperature and fish size in determining oxygen demand. Whereas size, temperature and food change a lot, sex ratio remains close to 1, and salinity and locomotory activity remain rather constant. The reproductive metabolism of the fish is not very important yet as the animals are still immature.

Sparre (1976) separates feeding catabolism from fasting catabolism and

thinks that the oxygen demand should be proportional to the sum of both.

Willoughby (1968) relates oxygen requirements to the total amount of food consumed when fish are fed according to the manufacturers' feeding guide. It gives a good estimate of loading capacities for a fish farm (Fauré, 1976).

Following Liao's method (1971), we tried to find a relationship between oxygen demand and temperature and the size of rainbow trout in fresh water for a given feeding level.

## MATERIALS AND METHODS

Various groups of rainbow trout with an average wet weight of 12–925 g were acclimated for 2 or 3 days in ponds where measurements were undertaken. The mean load was 5–10 kg m<sup>-3</sup>. Water supply and natural re-oxygenation of these ponds were well known.

While proceeding to measurements, the water-flow was adjusted so as to have 6 mg l<sup>-1</sup> dissolved oxygen at the outlet. Measuring started only 5 or 6 h after the last food intake.

Every 3 min for at least 1 h, the difference in oxygen content between inlet and outlet was checked and, in keeping with the method of Gorin et al. (1977), corrected according to surface exchanges. The average relative error when measuring dissolved oxygen demand (OD) is about 4%.

During the adaptation period, groups were fed in accordance with the usual tables produced by commercial fish-food manufacturers. This feeding level, which produces the maximum growth rate, is a common practice in fish farming. We then assumed the feeding level, which as a factor of variation in OD, to be accounted for. Digestion occurred while OD was measured, but the excitement which follows a food catch had stopped (Petit and Ferron, 1975).

In order to obtain the best regression in the OD of rainbow trout on temperature and wet weight, 52 different observations were made during 95 h, with temperatures ranging from 4 to 22° C.

The OD is related to fish weight and to time (mg kg<sup>-1</sup> h<sup>-1</sup>). The average unit wet weight,  $p$ , is expressed in grammes and temperature,  $t$ , in °C.

## RESULTS

At a constant temperature, the logarithm of the OD is linearly related to the logarithm of  $p$ .

We then considered an expression such as:

$$\log \text{OD} = a \log p + b.$$

The slopes have two different values,  $a_1$  and  $a_2$ , when temperatures are under 10° C and above 12° C. In each range of temperature,  $b$ , the intercept on the y-axis, seems to increase linearly with temperature, probably giving:

$$\log \text{OD} = A \log p + Bt + C \quad (1)$$

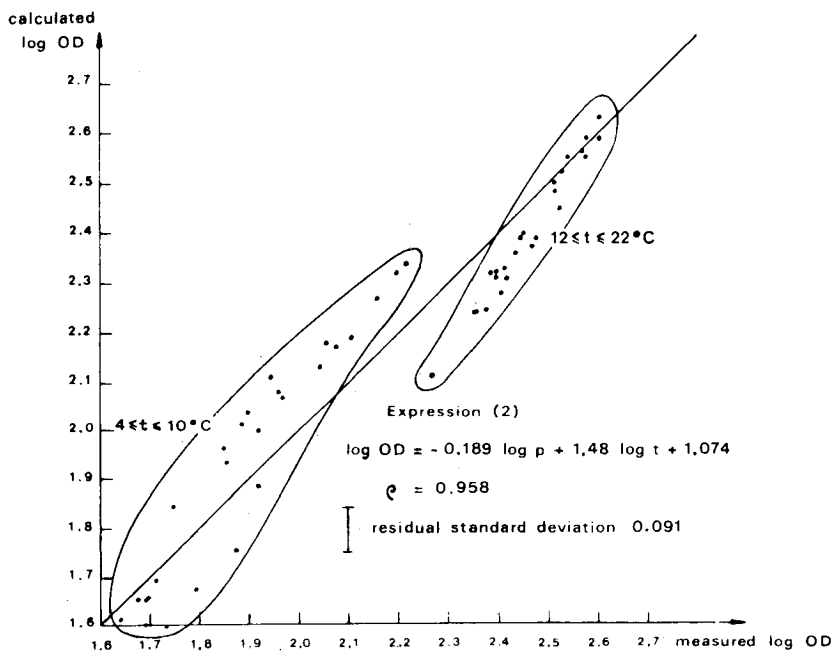
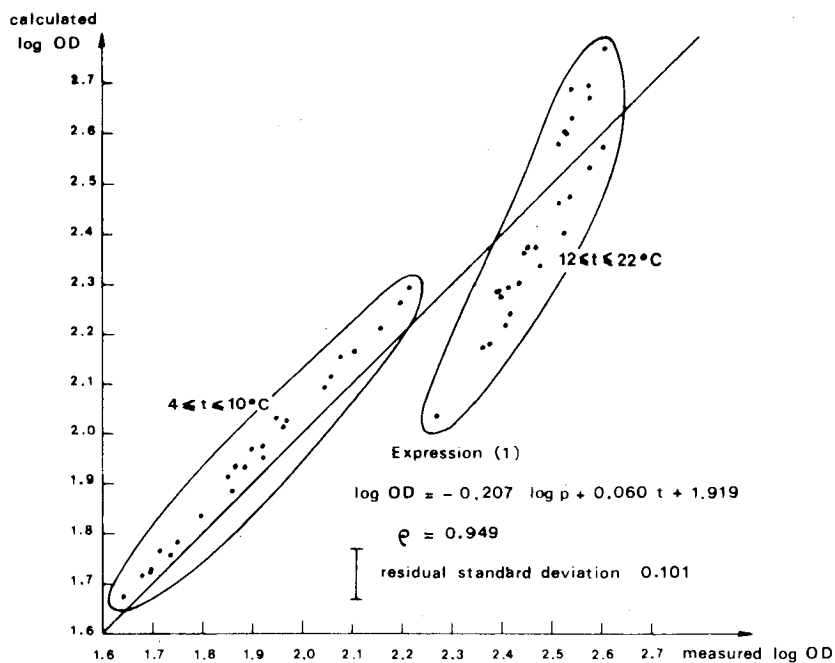


Fig. 1. Comparison between calculated and measured oxygen demand (OD) logarithm (4–22°C).

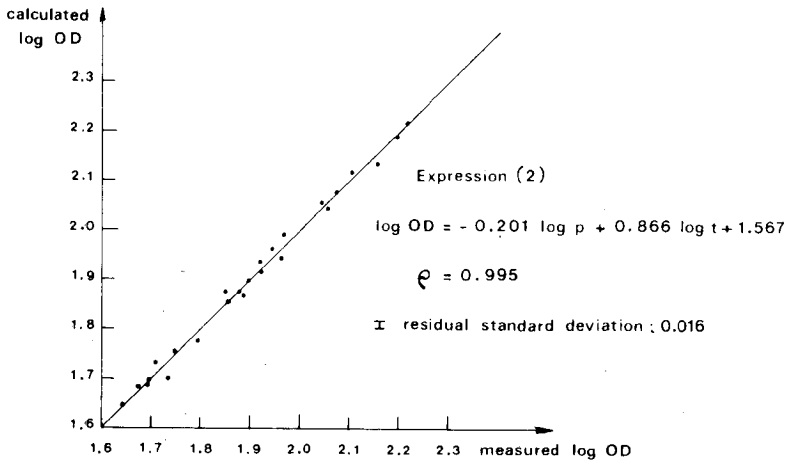
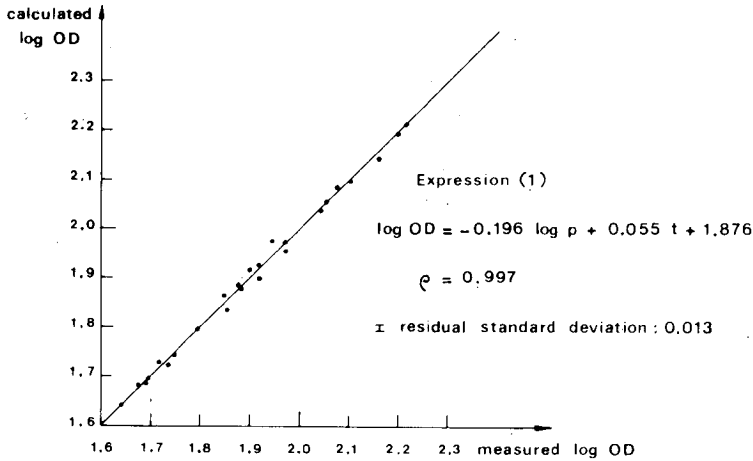


Fig. 2. Comparison between calculated and measured oxygen demand (OD) logarithm ( $4-10^{\circ}$  C).

As Liao (1971) introduced temperature under a logarithmic form, we also tested the following expression:

$$\log OD = A' \log p + B' \log t + C' \quad (2)$$

We tested (1) and (2) over the whole temperature range. With Fig.1, we can compare the observed values to those calculated through the linear regression coefficients we got for (1) and (2).

According to the graphic analysis, we shall separate the temperatures under  $10^{\circ}$  C from those above  $12^{\circ}$  C since the two groups of dots corresponding to those temperature ranges are clearly discontinuous, even though nothing in the choice of experimental conditions had ever suggested that this might be so.

When  $4 \leq t \leq 10^\circ \text{C}$ , multiple regression coefficients for (1) and (2) will be 0.997 and 0.995. Fig.2 illustrates the comparison between calculated and observed values. When  $12 \leq t \leq 22^\circ \text{C}$ , multiple regression coefficients in both expressions are equal to 0.995 (Fig.3). All the results of the multiple regression analysis applied to our experiments are summarized in Table I.

The only difference between multiple regression coefficients for expressions (1) and (2) will appear when  $4 \leq t \leq 10^\circ \text{C}$ . To find out if that difference is significant, we compared both regression coefficients through Fischer's function. As the probability of their being identical is over 0.95, it is impossible to say that one expression will give the better adjustment.

## DISCUSSION

As the expression (2) is identical to that of Liao (1971), we shall compare

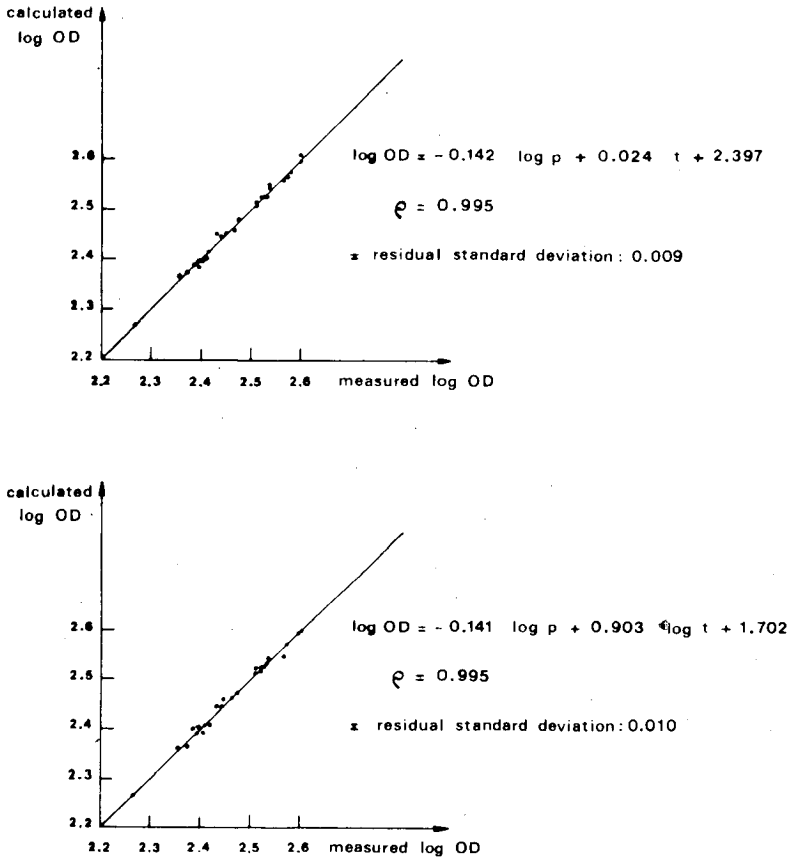


Fig.3. Comparison between calculated and measured oxygen demand (OD) logarithm ( $12-22^\circ \text{C}$ ).

TABLE I

Results of multiple regression analysis

Temperature range	Expression (1) log OD = $A \log p + Bt + C$	Expression (2) log OD = $A' \log p + B' \log t + C'$
$4 < t \leq 22^\circ \text{C}$	A = -0.207 B = 0.060 C = 1.919 $\rho = 0.949$ $\tau = 0.101$	A' = -0.189 B' = 1.492 C' = 1.074 $\rho = 0.958$ $\tau = 0.091$
$4 < t \leq 10^\circ \text{C}$	A = -0.196 B = 0.055 C = 1.876 $\rho = 0.997$ $\tau = 0.013$	A' = -0.201 B' = 0.866 C' = 1.567 $\rho = 0.995$ $\tau = 0.016$
$12 \leq t < 22^\circ \text{C}$	A = -0.142 B = 0.024 C = 2.397 $\rho = 0.995$ $\tau = 0.009$	A' = -0.141 B' = 0.903 C' = 1.702 $\rho = 0.995$ $\tau = 0.010$

- A and A' : regression coefficient of log OD versus log p  
 B : regression coefficient of log OD versus t  
 B' : regression coefficient of log OD versus log t  
 C and C' : constants  
 OD : dissolved oxygen demand mg.Kg<sup>-1</sup> h<sup>-1</sup>  
 p : mean trout wet weight g  
 t : temperature °C  
 $\rho$  : multiple regression coefficient  
 $\tau$  : residual standard deviation

them. Liao studied two ranges of temperature showing a discontinuity near 10° C; this confirms our own results.

Liao's equation may also take the following form:

$$\log O_2 = m \log W + n \log T + K'$$

$O_2$  = oxygen demand for 100 kg fish wet weight per day (kg)

$T$  = water temperature (° F)

$W$  = mean wet weight (pounds).

$m$  should then be equal to our A'. The only value Liao kept for  $m$  (-0.138) is similar to the A' value we got for  $12 \leq t < 22^\circ \text{C}$  (A' = -0.141).

In our expression (2) and in Liao's equation, temperature appears as a power function and, on the contrary, as an exponent in expression (1). We may choose either expression as both are equivalent; therefore we shall keep ex-

pression (1), temperature being more often found under an exponential form in physiology. Besides, it will allow the introduction of the  $Q_{10}$  concept (activity ratio at  $t + 10^\circ\text{C}$  and  $t$ ).

Summing up, we get:

$$\text{OD} = \alpha \cdot p^\beta \cdot 10^{\gamma t}$$

where:

OD : oxygen consumption per hour for 1 kg fish ( $\text{mg kg}^{-1} \text{h}^{-1}$ )

$p$  : mean fish wet weight (g)

$t$  : temperature ( $^\circ\text{C}$ )

and:

$$Q_{10} = 10^{10\gamma}$$

The constants obtained for rainbow trout in fresh water are given in Table II. These calculated results can be seen graphically in Fig.4.

TABLE II

Constants for rainbow trout in fresh water

	$4 \leq t \leq 10^\circ\text{C}$	$12 \leq t \leq 22^\circ\text{C}$
$\alpha$	75	249
$\beta$	-0.196	- 0.142
$\gamma$	0.055	0.024
$Q_{10}$	3.5	1.7

## CONCLUSION

The mathematical model we obtained allows an estimation of the oxygen demand of the rainbow trout in a period of an hour. It is not yet quite perfect because of the indetermination between  $10$  and  $12^\circ\text{C}$ , and its use is restricted to the feeding level used in practice.

This model gives an OD estimate with a relative error (95% confidence level) equal to 6% when  $4 \leq t \leq 10^\circ\text{C}$  and 4% when  $12 \leq t \leq 22^\circ\text{C}$ , and mainly due to inaccuracy in measuring when applied under to the following conditions:

- a feeding level based on fish-food manufacturers' tables
- clean ponds and good water standards
- more than  $6 \text{ mg}^{-1}$  oxygen
- an average load between 5 and  $10 \text{ kg}^{-3}$ .

It leads to the  $Q_{10}$  concept, which remains constant at temperatures below  $10^\circ\text{C}$  and above  $12^\circ\text{C}$ . Its value for the lower temperature range is double that for the upper one.

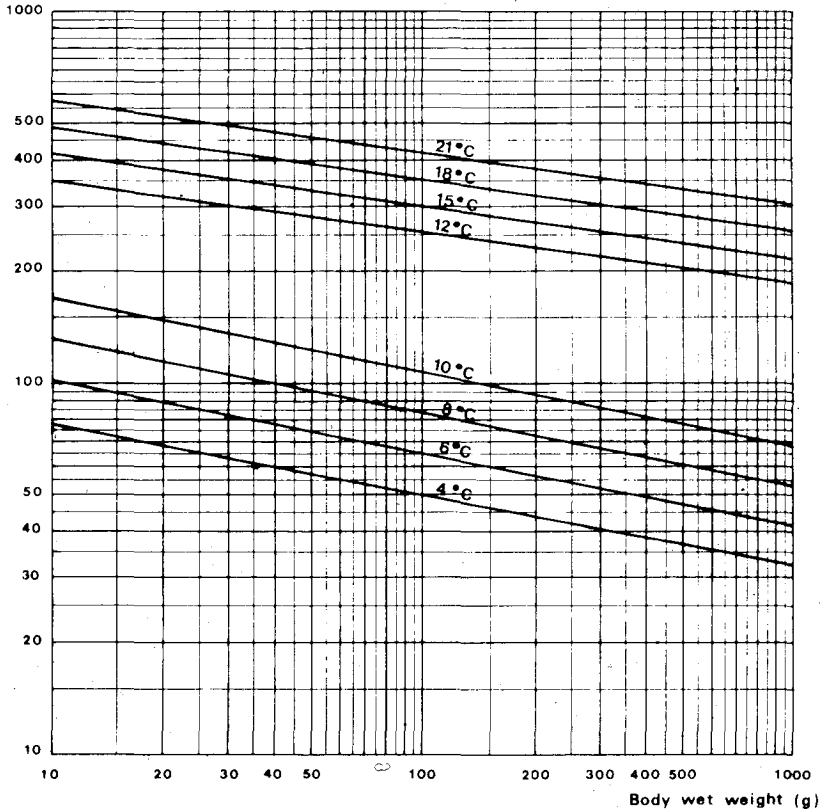
OD ( $\text{mg} \cdot \text{Kg}^{-1} \cdot \text{h}^{-1}$ )

Fig. 4. Oxygen consumption ( $\text{mg O}_2$  per kg of fish per hour) of rainbow trout related to body wet weight at different temperatures in fresh water.

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## RESUME

- Muller-Feuga, A., Petit, J. et Sabaut, J.J., 1978. Influence de la température et du poids vif sur la demande en oxygène de la truite arc-en-ciel (*Salmo gairdneri* R.) en eau douce. *Aquaculture*, 14: 355—363 (en anglais).

L'analyse des corrélations multiples appliquée à une série de mesures de la demande en oxygène chez la truite arc-en-ciel confirme le caractère déterminant de la température et de la taille des poissons dans les conditions standard d'alimentation. Deux types d'ajustement de la demande en oxygène en fonction de ces deux paramètres sont étudiés. L'un d'entre eux est retenu. Il fait intervenir la température sous une forme exponentielle et permet d'introduire la notion de  $Q_{10}$ . Celui-ci diffère d'un facteur 2 selon que la température est inférieure à 10° C ou supérieure à 12° C.