

OXYGEN CONSUMPTION RATE AS A FUNCTION OF  
TEMPERATURE AND STARVATION OF THE VELIGERS OF  
EDIBLE OYSTER *CRASSOSTREA GIGAS* (THUNBERG)

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ABSTRACT

Oxygen consumption rates ( $\mu\text{LO}_2/\text{h}/\text{larva}$ ) were measured at three temperature levels 13°C, 20°C and 25°C after 1, 3, 6 and 9 days from the last meal. The highest rate (24.4  $\mu\text{LO}_2/\text{h}/\text{larva}$ ) resulted from the combined effect of 25°C and after 12 hours from the last meal, while the lowest one (4.2  $\mu\text{LO}_2/\text{h}/\text{larva}$ ) recorded at 20°C and after 9 days starvation. After 9 days starvation, the oxygen consumption rates were not affected with temperature.

INTRODUCTION

AS POINTED out by Zeuthen (1953), the words 'respiration', 'metabolism' and 'oxygen uptake' would all be to mean 'oxygen uptake' per hour per organism, while the terms 'respiratory rate' and 'rate of oxygen uptake' would all be defined as 'oxygen uptake per hour per unit of body size'.

Newell and Northcroft (1967) reinterpreted the effect of temperature on the metabolism of certain invertebrates especially the bivalve *Cardium edule*. Newell and Pye (1970) examined the influence of thermal acclimation and seasonal changes on the relation between oxygen consumption and temperature in *Littorina littorea* and *Mytilus edulis*. Boyden (1972) studied the respiration of cockles *Cerastoderma edule* and *C. glaucum* in the air. Thompson and Bayne (1972) found that the mussel *M. edulis* responded to a food stimulus by increasing the rates of oxygen consumption above the routine values. They suggested the presence of a clear distinction between an

active metabolism related to feeding in the short-term, a routine metabolism associated with long-term feeding and a standard metabolism attained after prolonged starvation. Widdows (1973) identified the term standard metabolism as the minimum energy requirement for the maintenance of all vital functions within an inactive organism, routine metabolism as the rate which includes the energy demands of spontaneous activity and the active metabolism is the level of oxygen consumption under conditions of maximum activity. Bayne and Scullard (1977) confirmed the decline in the rate of oxygen uptake by *M. edulis* during starvation, eventually reaching the standard metabolism. Riisgard *et al.* (1980) stated that oxygen consumption rates and rates of water processing in plankotrophic mussel and other bivalve larvae are basic parameters in bioenergetic studies of the larvae which constitute important component of marine zooplankton. Shummway (1983) examined the factors affecting oxygen consumption of the coot clam *Mulinia lateralis*.

In the last decade, the investigators oriented their efforts to study the influence of temperature and food availability on the respiration rates of the giant scallop *Placopecten magellanicus*. MacDonald and Thompson (1985/ a, b), MacDonald *et al.* (1987) and Bricelj *et al.* (1987) found that the oxygen consumption of the bay scallop *Argopecten irradians irradians* was closely related and parallel to seasonal changes in water temperature.

There is lack of data in the literature concerning oxygen consumption rates of bivalve mollusc larvae. Accordingly, this study is undertaken to provide information on some of the ways in which temperature and starvation time affect the rates of oxygen consumption of these organisms.

oyster hatchery of Quilcene, Washington. They were shipped damp and cool by air freight (Jones and Jones, 1982). On arrival to the laboratory, the larvae were acclimated to the room temperature slowly before being placed in the artificial sea water (28‰ and 20°C). They were maintained on a mixture of 100 cells (1 : 1) of *Isochrysis galbana* Parke and *Pavlova lutheri* Droop. The larvae were reared according to the method of Loosanoff and Davis (1963).

The experimental ranges of temperature (13°C, 20°C and 25°C) and time of starvation (¼, 3, 6, 9 days from the last meal) were run sequentially, corresponding as closely as possible to field conditions to minimize accli-

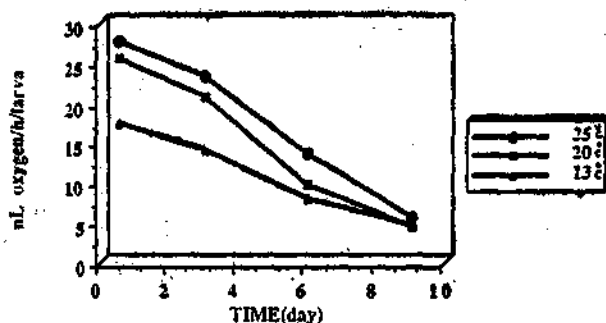


FIG. 1. The combined effect of nutritional levels and temperature degrees on the oxygen consumption rate of young larvae.

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#### MATERIAL AND METHODS

Larvae of the Pacific oyster *Crassostrea gigas* (Thunberg) were obtained from coast

mation time and potential seasonal biases (Robert *et al.*, 1988).

Three sets of 200 veligers of average body size  $155 \pm 5 \mu\text{m}$  were prepared to measure the oxygen consumption rate at 13°C, 20°C and 25°C. The measurements were taken after ¼, 3, 6 and 9 days from the last meal. Oxygen consumption rates of the larvae were measured in closed glass respiratory chambers of 50 ml capacity fitted with a rotor and Clark electrode (yellow spring Instruments, YSI No. 53).

## RESULTS

*Effect of temperature on oxygen consumption rate*

Regardless the nutritional levels of the veligers, the percentage of oxygen calculated from the two successive reading under the effect of constant consumption of oxygen is given in Table 1. The difference between the percentage of oxygen consumed by the veligers at zero minute from starting the experiments and that after 80 minutes relied on the tested temperature.

TABLE 1. Percentage  $O_2$  consumption by 200 young larvae of average body size ( $155 \pm 5 \mu m$ ) after  $\frac{1}{2}$ , 3, 6 and 9 days from the last meal at temperature  $25^\circ C$ ,  $20^\circ C$  and  $13^\circ C$

Temperature ( $^\circ C$ )	Time from start- ing expt. (min.)	Percentages of oxygen			
		$\frac{1}{2}$	3	6	9
25	0	94.1	95.6	94.5	84.5
	20	83.9	89.4	92.1	93.1
	40	79.7	83.2	87.4	91.8
	60	72.3	77.3	83.7	90.4
	80	62.0	71.2	81.3	88.8
20	0	96.4	95.2	95.7	95.1
	20	90.4	94.1	93.4	95.7
	40	86.5	85.2	91.1	93.9
	60	78.7	80.5	88.7	93.0
	80	74.6	75.3	86.6	92.0
13	0	95.6	95.5	96.1	95.4
	20	91.7	92.4	94.2	94.6
	40	91.5	89.3	92.3	94.0
	60	84.0	86.3	90.8	92.4
	80	80.4	83.1	89.3	91.5

The regression coefficient  $b$  (slope) that derived from the regression equation also ascertain the effect of temperature on the percentage of the oxygen. The slope  $b$ , which is the percentage of oxygen/minute, increased by increasing the temperature. The  $b$  values of the fed larvae (12 hours from the last meal) were  $-0.379$ ,  $-0.277$ ,  $-0.191$ . Minus sign proceeded these

values, because the reading decreased by the passage of time.

The oxygen consumption rates were larger at the higher temperature than that at the lower one. In the fed larvae, they were 27.39, 25.43 and 13.3  $\mu l O_2/h/larva$  at  $25^\circ C$ ,  $20^\circ C$  and  $13^\circ C$  respectively (Table 2).

*Effect of starvation on oxygen consumption rate*

The oxygen consumption rates were greatly affected when the feeding regions of the larvae changed from to starved case (Table 2). From the data included in Table 2, it can be found that the oxygen consumption rates of the fed larvae were larger than that of starved ones. Moreover, the rates of starved larvae also, differed according to the degree of starvation. For example, at  $25^\circ C$ , they were 23.01, 13.43 and 5.36  $\mu l O_2/h/larva$  after 3.6 and 9 days from the last meal respectively.

*Combined effects of temperature and nutritional levels on oxygen consumption rate*

The largest rate (27.4  $\mu l O_2/h/larva$ ) resulted from the combined effects of  $25^\circ C$  and 12 hours from the last meal (fed) followed by the combination  $20^\circ C$  and 12 hours and then  $25^\circ C$  and 3 days starvation. It is also clear that, the rates of oxygen consumption of the larvae that starved for 9 days were not affected, in any way, with the temperature where these rates were 5.3, 4.2 and 4.5  $\mu l O_2/h/larva$  at  $25^\circ C$ ,  $20^\circ C$  and  $13^\circ C$  respectively.

## DISCUSSION

Metabolic rates of larvae are comparable with those of meiofauna and zooplankton organisms. According to Lasserre (1976) metabolic rates of meiofauna can be assumed to lie between 0.4 and 12  $\mu l O_2/h/mg$  dry weight. He calculated respiration in relation to wet weight and here it is used the maximum length of the larvae where the length of the larval

shell could be used as a function of body dry weight (Riisgard *et al.*, 1980).

TABLE 2. A comparison between the regression equation elements, resulted in the effect of different temperature on the fed and starved young larvae (155 + 5  $\mu$ m) and the  $O_2$  consumption rate of these larvae

Temperature (°C)	Days from the last meal	Regression analysis			$O_2$ consumption rate ( $\mu$ l $O_2$ /h/ Larva)
		a	b	r	
25	½	94.2	-0.379	-0.991	27.39
	3	95.5	-0.305	-0.999	23.01
	6	94.5	-0.178	-0.999	13.43
	9	94.5	-0.071	-0.994	5.36
20	½	96.6	-0.277	-0.995	25.43
	3	96.7	-0.267	-0.983	20.49
	6	95.7	-0.115	-0.999	9.54
	9	96.3	-0.055	-0.986	4.23
13	½	96.3	-0.191	-0.966	17.30
	3	95.5	-0.151	-0.999	13.68
	6	95.9	-0.085	-0.999	7.70
	9	95.6	-0.050	-0.988	4.50

a = Intercept (Constant value)

b = Slope (%  $O_2$ /min.)

r = Correlation coefficient.

The relationship between oxygen consumption and values of size exponent (*b*) show much interspecific variation within different invertebrate groups (Berg and Ockelmann, 1959; Wolvekamp and Waterman, 1960). Amongst bivalves, there are not only interspecific difference in the value of *b*, but studies of the same species by different workers have produced varied values for this experiments. In *Cardium edule*, for example, these range between -0.56 (Boyden, 1972), -0.48 (Newell and Northcroft, 1967) and -0.23 (Vahl, 1972). Similarly, values for *M. edulis* vary from +0.027 (Bayne, 1971 a) to -0.43 (Rotthauwe, 1958). In both these species, the variations are perhaps attributable to the

fact that different population were studied or to difference in experimental conditions. The value of *b* +0.027 obtained by Bayne (1971 b) in *M. edulis* would appear to be anomalous since the graph relating oxygen consumption rate to body size has a positive slope indicating that the rate increase with increasing the size. The *b* values of the present study occupy the same area that includes the *b* values of the previously mentioned literature. The *b* of this study fluctuated between -0.26 to zero. Only two anomalous *b* values recorded after 9 days starvation at 25°C and 20°C.

Temperature is also known to affect the value of the exponent *b* as shown by the work of Newell and Roy (1973) on the gastropod *Littorina littorea* Newell and Northcroft (1967) on the bivalve *C. edule*. In view of the fact that *b* can show interspecific variations according to temperature the difference in the *b* obtained for larvae in the present study may probably be attributed to this factor and to the possibility of physiological differences between populations, rather than to changes in the relationship between oxygen consumption rate and body size (unpublished data). Although the effect of temperature on the oxygen consumption rate is very clear in this study, it is found that, these rates were not affected by the temperature after 9 days starvation. This observation shows that temperature has no absolute effect on the oxygen consumption rate when the stage of standard metabolism has been arrived.

Kleiber (1961) stated that the standard metabolic level is equivalent to the rate of fasting catabolism and may be defined as the metabolic rate compatible with the maintenance of a functionally integrated organism. Bayne (1973) has shown that *M. edulis* reduces its oxygen consumption to a steady state after a period of 30 days starvation at 15°C. This and our results are taken to represent standard metabolism by Kleiber's definition.

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