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OBSERVATIONS ON THE EFFECT OF DISSOLVED OXYGEN AND TEMPERATURE ON RESPIRATION RATES OF THE BAY SCALLOP, *Argopecten irradians*

The bay scallop, *Argopecten irradians*, regulates its respiratory activity over a wide range of DO concentrations at temperatures of 17°C to 22°C (Van Dam 1954). Northern bay scallops, however, are physiologically active at temperatures below 17°C (Bricelj et al. 1987). The potentially significant influence of interactions between environmental variables, such as DO and temperature, on metabolic activity of aquatic animals has been emphasized (Shumway 1982). A limiting factor such as DO may act to restrict the potential range of activity of an aquatic animal (Fry 1947). It was thus the goal of this study to evaluate the possible restricting effect of DO on bay scallop respiration rates at a temperature lower than those examined by Van Dam (1954).

MATERIALS AND METHODS

Animals were collected from scallop beds at Greenport on Long Island, New York, during the month of April, 1971. In the laboratory, they were held in flowing seawater at ambient temperature and 30 ‰ salinity. Five to seven days prior to exposure groups of scallops were transferred to a re-circulating seawater system containing seawater also at 30 ‰ salinity and saturated DO. During this period scallops were acclimated to the test temperatures (10°C and 20°C) and were fed *Isochrysis galbana*.

Experimental system and procedures used in measuring oxygen consumption are described in Voyer and

Morrison (1971). Briefly, desired DO concentrations are achieved by stripping oxygen from air-saturated water with nitrogen gas. The water is then passed through respirometers, reaerated and recirculated. The system allows concurrent evaluation of three DO levels per test and three replicates per DO concentration. A blank respirometer without scallops at each DO level provides an estimate of the oxygen demand of the test water. Experimental procedures involved placing 1 to 3 scallops of comparable size into each of three replicate respirometers approximately 24 hours before measurements were begun. Dissolved oxygen concentrations were then lowered to desired levels over the next 3 to 6 hours. Six tests were performed during April-May at 10°C and DO of 8.7, 4.3 and 1.6 mg/liter, and eight tests during June-August at 20°C and DO concentrations of 7.4, 4.0 and 2.4 mg/liter. Oxygen content of water from each respirometer was measured twice over a 4-5 hour period using a YSI Model 54-oxygen meter calibrated with the azide modification of the Winkler Method (APHA 1965). The difference in DO of a blank and a scallop-bearing respirometer was a measure of oxygen consumed by scallops. At the completion of an experiment, scallops were shucked, total soft parts drained on absorbent paper and weighed to the nearest 0.1 gm.

For data analysis, the two measurements of oxygen consumed by scallops in each replicate of a test were first averaged. Mean respiration rates and scallop wet weights were then rectified using a \log_{10} transformation. Results were analyzed by least squares (SAS 1985) to determine the influence of wet weight on routine respiration at each DO concentration at both temperatures. Calculations used the following model: $\hat{Y} = a + b \log_{10} X$, where $\hat{Y} = \log_{10}$ routine respiration, a and b = estimated

regression coefficients, $X = \log_{10}$ wet weight in gms. The equality of slope coefficients was evaluated by analysis of covariance (SAS 1985). Data were also combined by temperature and analyzed using covariance techniques to assess the effect of temperature, as well as by linear regression analysis to determine respiration-weight relationships averaged over DO concentrations at 10°C and 20°C.

Respiration-weight coefficients are significantly different from zero at all DO-temperature treatments ($P < 0.05$). All coefficients but one are positive in value, signifying that small scallops consume more oxygen than large ones in all but one instance (Table 1). Response variability increases as DO concentration decreases. The regression model, as a result, accounts for progressively less experimental variability at each successively lower DO concentration. R^2 values decrease from 0.79 at 7.4 mg DO/liter to 0.13 at 2.0 mg DO/liter at 20°C, for example (Table 1). Also, the magnitude of slope coefficients is inversely related to DO. Coefficients within a temperature treatment, however, do not differ statistically from one another, a result indicative of the comparatively greater variability of responses associated with exposure to DO below saturation concentrations. The consistent pattern of slope change may be noteworthy, nevertheless, as estimated respiration rates for scallops at 20°C and 2.0 mg DO/liter indicate a decrease in respiratory activity to the level observed at 10°C (Fig. 1). This potential limiting effect of DO implies that reductions in DO concentration could restrict the upper thermal tolerance limit of the bay scallop (Fry 1947), in that the expenditure of energy must also increase with increases in environmental temperature (Shumway 1982).

Estimated rates of oxygen consumption presented in Figure 1 suggest that

scallops at 20°C consumed about 60% more oxygen than did those at 10°C. Analysis of covariance of pooled responses tends to confirm that this temperature related difference in respiratory activity is significant ($P < 0.05$).

Van Dam (1954) concludes that respiration of the bay scallop is independent of DO concentration to about 2.0 mg/liter. Experimental evidence presented here supports this judgment. It also implies that the critical DO concentration, as well as adaptive strategies of this species to reduced DO, may be related to animal size and temperature. For example, the negative slope coefficient (-0.99) recorded at the 10°C-1.6 mg DO/liter treatment (Table 1) is due to increased and decreased rates of oxygen consumption by scallops weighing <6 gms and >6 gms, respectively (Fig 1). In addition, no oxygen consumption by scallops >7 gms occurred in two

Table 1. Regression equations representing respiration of bay scallops of varying wet weights (0.9-11.1 gms at 10°C, 2.9-4 gms at 20°C) at different temperature-dissolved oxygen treatments. X = wet weight, R^2 = correlation coefficient.

Treatment	Equation $\hat{Y} = a + b \log_{10}X$	R^2
10°C		
8.7 mg DO/L	$\log_{10}\hat{Y} = -0.92 + 0.77 \log_{10}X$	0.98
4.3 mg DO/L	$\log_{10}\hat{Y} = -0.99 + 0.78 \log_{10}X$	0.84
1.6 mg DO/L	$\log_{10}\hat{Y} = 0.42 - 0.99 \log_{10}X$	0.20
20°C		
7.4 mg DO/L	$\log_{10}\hat{Y} = -0.72 + 0.85 \log_{10}X$	0.79
4.0 mg DO/L	$\log_{10}\hat{Y} = -0.97 + 1.09 \log_{10}X$	0.44
2.0 mg DO/L	$\log_{10}\hat{Y} = -1.60 + 1.62 \log_{10}X$	0.13
Responses to DO Pooled By Temperature		
10°C	$\log_{10}\hat{Y} = -0.72 + 0.75 \log_{10}X$	0.92
20°C	$\log_{10}\hat{Y} = -0.93 + 1.01 \log_{10}X$	0.23

instances in this DO concentration. Results of this study do not provide a ready explanation for this negative relationship or its implications. Enhanced metabolic rate displayed by smaller scallops, however, may be energetically damaging (Bayne 1980). In this vein large specimens of *Mytilus perna* (Bayne 1967) and *Spisula solidissima* (Thurberg and Goodlett 1979) were more tolerant of DO reductions than small ones. Bayne (1971) has suggested that the influence of body size on DO tolerance may be directly related to the higher weight-specific oxygen consumption rate of smaller animals.

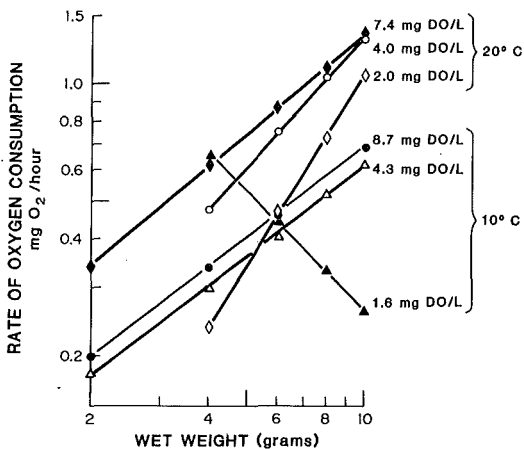


Fig. 1. Estimated respiration rates of *Argopecten irradians*. Each point represents the rate of oxygen consumed by a scallop of selected size estimated using regression equations presented in Table 1. 20°C: ◆ = 7.4 mg DO/liter, ○ = 4.0 mg DO/liter, ◇ = 2.0 mg DO/liter; 10°C: ● = 8.7 mg DO/liter, △ = 4.3 mg DO/liter, ▲ = 1.6 mg DO/liter.

Gonadal maturation of the bay scallop was closely correlated with seasonal changes in temperature and food supply (Sastry 1975). Sastry also suggests that gonadal development may be secondary to the maintenance requirements of this species. It is thus conceivable that increases in metabolism attendant with exposure to hypoxia can disrupt not only normal transfer of energy to the developing gonad, but also

synchrony of events in the reproductive cycle. A 50% increase in metabolic activity coincides with gametogenic activity in young scallops in May when temperatures (10-15°C) approximated the low temperature investigated in this study (Bricelj et al. 1987).

Persistent hypoxic events have been recorded in the New York Bight (Swanson and Sinderman 1979) and portions of Long Island Sound (Parker and O'Reilly 1991). In the case of the New York Bight, extensive mortality among surf clams, quahogs and sea scallops accompanied the low oxygen conditions. Results of this study thus suggest that episodes of hypoxia may have long-term implications for a species such as the bay scallop, in addition to effecting short-term mortality.

Locomotor activity exhibited by scallops in respirometers was not monitored. However, increased variability of responses associated with low DO suggests elevated levels of physical activity. Increases in such activity may be a part of the scallop response to reductions in DO. If so, analysis of activity in conjunction with changes in respiration rates may offer a useful means of assessing the onset of hypoxic-related stress in this species.

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