Aerial respiration of *Cerithidea (Cerithideopsilla) cingulata* (Gmelin) and *Cerithium coralium* Kiener in relation to body weight

Y PRABHAKARA RAO and D G V PRASADA RAO
Department of Zoology, Andhra University, Waltair 530 003, India

Abstract. An exponential increase in oxygen consumption was observed with increase in size of *Cerithidea cingulata* and *Cerithium coralium* at 25°C. The *b* and (*b*-1) values were calculated for both. The aerial regression values were compared with aquatic values.

Keywords. Aerial respiration; cerithiids; aquatic respiration; body size; *Cerithidea cingulata*; *Cerithium coralium*.

1. Introduction

Population of cerithiids form an important part of the total animal biomass of the backwater system of Bhimilipatnam, 35 km from Visakhapatnam. Therefore, the impact of these animals on the energy and nutrient budgets of the ecosystem needs to be investigated. The present investigation is a part of the study representing the effect of body size on the aerial respiration of *C. cingulata* and *C. coralium*. Moreover, these cerithiids inhabit different regions of backwater system: *C. coralium* towards wave-swept regions and *C. cingulata* towards more exposed area. Investigations on the aquatic and anaerobic metabolisms of these cerithiids have already been reported (Prabhakara Rao and Prasada Rao 1981a,b).

2. Material and methods

The animals collected from the backwaters of Bhimilipatnam, were kept in the laboratory for 24 hr in running seawater (32%). They were not fed before and during experimentation. Respiratory measurements were made using Warburg Respirometer (B. Braun, Apparatebau, Melsungen) (Umbreit *et al* 1959) with 25 ml flasks. Potassium hydroxide solution (10%) was used to absorb carbondioxide. The bottom of the flask was wetted with Whatman 42 filtered seawater. Aerial oxygen consumption was determined at a constant temperature of 25°C. Preliminary experiments showed that the aerial oxygen consumption was fairly constant for 24 hr after acclimation of 3-4 hr. Single animal was used in each experiment. Respiratory measurements were taken every 2 hr interval over a period of 6 hr. In smaller animals, readings were taken after 6 hr and the average hourly oxygen consumption was calculated. After the experiment, the soft parts were removed after breaking the shell and dried to a constant weight at 110°C. Sixty animals were used for the experiment and they were assorted into 14 (dry weight of soft parts ranges from 11 to 167 mg) and 11 (dry weight of soft parts ranges from 8 to 73 mg) size

groups in *C. cingulata* and *C. coralium* respectively. Animals of about the same body weight were all averaged into-different size groups and only the average body weight and hourly oxygen consumption were considered for the presentation of the data and statistical analysis. The allometric equation $O_2 = aW^b$ (Zeuthen 1953) was used to express the relationship of oxygen consumption to size. The regression values were calculated using the method of least squares (Snedecor and Cochran 1967). The regression lines were fitted for the calculated values and the observed values were plotted over them. For comparing the regression coefficients, *t* values were calculated following Student's *t* test (Goulden 1962).

3. Results

In both the animals, a positive correlation was obtained when oxygen consumption was plotted against body weight on a double log plot (figure 1) and a negative linear correlation was observed when the plot was drawn for metabolic rate against body weight (figure 2). Oxygen consumption increased with increase in weight in both the animals and exhibited an exponential relationship. A regression value of 0.756 was observed for *C. cingulata* and 0.8943 for *C. coralium*. The corresponding regression value for weight specific oxygen consumption is −0.244 in *C. cingulata* and −0.1057 in *C. coralium*. The former positive values represent *b* and the latter negative values correspond to (*b*− 1). These values with their standard errors are furnished in table 1.
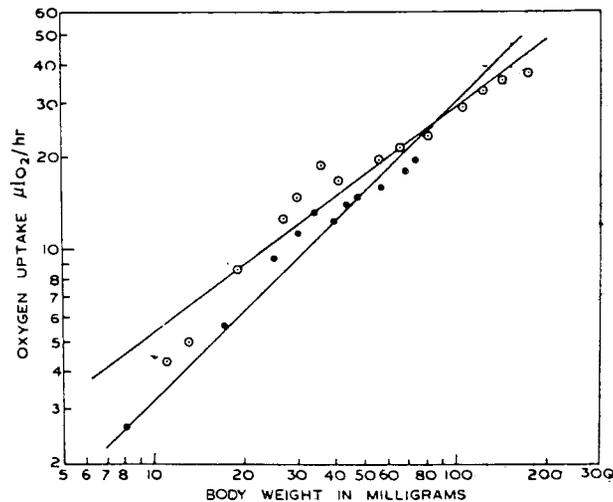

Figure 1. Relationship of oxygen consumption (aerial) and body weight in *Cerithidea cingulata* (☉) and *Cerithium coralium* (●).
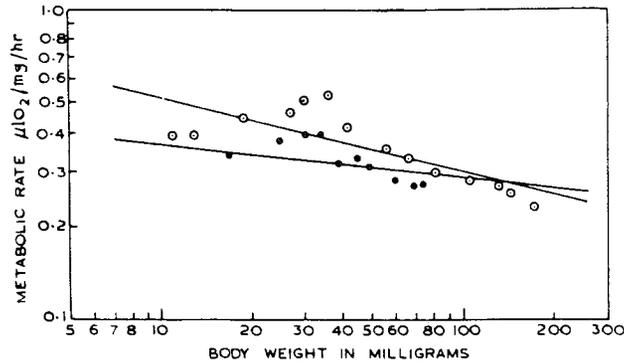
Figure 2. Relationship of metabolic rate (aerial) and body weight in *Cerithidea cingulata* (O) and *Cerithium coralium* (●).

Table 1. The coefficients of weight specific oxygen consumption of *C. cingulata* and *C. coralium* and comparison with other regression coefficients.

	No.	b	$(b-1)$	Poikilotherms Hemmingsen: 0.75	Mollusca: 0.7	Common regression value of Patella: 0.6958	Aquatic values of C. cingulata: 0.6518 C. coralium: 0.7667
Cerithidea cingulata r: 0.9703 S_b : 0.05439	14	0.7560	−0.2440	0.0060	0.0560	0.0602	0.1042
				0.1103	1.0296	1.1068	1.9158
				0.1000	0.1000	0.1000	0.1000
Cerithium Coralium r : 0.9802 S_b : 0.05284	11	0.8943	−0.1057	0.1443	0.1943	0.1985	0.1276
				2.7309	3.6771	3.7566	2.4148
				0.1000	0.1000	0.1000	0.1000

Under each animal is given the correlation coefficient and the standard error of the regression coefficient; Under each comparison are given the differences in the regression coefficients, the t-value and the probability of obtaining a t value greater than or equal to the observed value.

t value for *C. cingulata* and *C. coralium* at 0.1000 level of significance : 1.8238.

4. Discussion

The ability of poikilotherms to respire both in air and water was first reported by Raffy (1933) and in some of the littorines by Fisher *et al* (1933). Later aerial oxygen consumption was demonstrated in many other molluscs (Newell 1979; Houlihan 1979; Widdows *et al* 1979; Griffiths 1981). In the present investigation both the animals exhibited aerial respiration but they showed changes with the weights. It is evident that the oxygen consumption per unit time is less in smaller animals, but the metabolic rate or weight specific oxygen consumption is high for smaller ones and

less for larger ones. The aerial oxygen consumption exhibited an increase with 0.756 and 0.8943 power of the body weight and the weight specific oxygen consumption with -0.2440 and -0.1057 power of the body weight in *C. cingulata* and *C. coralium* respectively.

The *b* values of *C. cingulata* and *C. coralium* show a departure from the 'surface law of Bertalanffy (1957) who proposed a quantitative relationship between metabolism and growth in various animals. A comparison of the *b* values of both the animals reveals that the value of *C. coralium* is significantly different ($p < 0.1$) from that of *C. cingulata* (table 1). Similar relationship has also been observed in aquatic rates of respiration of these cerithiids (Prabhakara Rao and Prasada Rao 1981a). They have reported regression values of 0.6518 for *C. cingulata* and 0.7667 for *C. coralium* for aquatic respiration. It is apparent from the comparison of aerial and aquatic regression values (table 1) that the regression values of aerial respiration are significantly different ($P < 0.1$) from that of aquatic respiration in both the animals. According to Zeuthen (1947), the *b* value for molluscs was 0.7 but Hemmingsen (1960) reviewed the literature on this aspect and a *b* value of 0.751 was proposed for poikilotherms. A comparison of the aerial regression values of both the cerithiids with that of 0.7 for molluscs of Zeuthen (1947) and 0.751 of Hemmingsen (1960), shows no significant difference ($p > 0.1$) for *C. cingulata*, while significant difference ($P < 0.1$) was observed for *C. coralium*. Davies (1966) made intraspecific and interspecific comparison of *Patella* species, *P. aspera* and *P. vulgata* from different levels and found that there was no significant difference in the effect of body weight on the metabolic rate. Therefore, a common regression coefficient of 0.6958 was adopted by him. This value (0.6958) was compared with the aerial regression values of the cerithiids. In *C. cingulata*, no significant difference was found ($P > 0.1$) but in *C. coralium*, there was a significant difference ($P < 0.1$) (table 1). However, it is clear that the regression value of *C. cingulata* is not significantly different and that of *C. coralium* is significantly different when compared with other regression values (table 1) showing species specificity as reported earlier for aquatic respiration (Prabhakara Rao and Prasada Rao 1981a).

Murdoch and Shumway (1980) measured the aerial and aquatic oxygen consumption of six species of chitons in relation to size and habitat. They observed that the regression values of aerial respiration (0.62–0.82) were found to be higher than that of aquatic regression values (0.37–0.48) in all six species. Toulmand (1967) also observed low *b* values in water (0.34–0.55) than in air (0.62–0.79) in several species of *Littorina*. In the present investigation, the results of high aerial regression values than that of aquatic, corroborates with those reported by Murdoch and Shumway (1980) and Toulmand (1967). They suggested that this variation might be due to their difference in the respiratory surfaces exposed to water or air.

From a comparison of aquatic (Prabhakara Rao and Prasada Rao 1981a) and aerial rates of respiration, it is clear that the aquatic rates are higher than the aerial rates. Similar increase of aquatic rates were observed in *Mytilus edulis*, *M. galloprovincialis*, *Cardium edule* and *Modiolus demissus* (Widdows *et al* 1979). Micallef (1967) stated that the ability of the species to utilise atmospheric oxygen was one of the factors to determine their distribution. Murdoch and Shumway

(1980) reported that high shore chitons had higher or equal respiratory rates in air than in water, while low shore chitons had higher aquatic than aerial rates of respiration. Therefore, from the higher rates of aquatic respiration in cerithiids, it is obvious that these animals are more adapted to aquatic respiration than to aerial respiration. In the habitat, these animals have adapted to take aerial oxygen during low tide period. Figure 1 also shows that the aerial rates of *C. cingulata* are higher than that of *C. coralium*. This might be due to its distribution: *C. cingulata* is more adapted to take aerial oxygen, because of its distribution towards more exposed areas, whereas, *C. coralium* is less adapted to aerial respiration because of its distribution towards wave-swept regions in the habitat. Similar habitat relationships were also reported by Sandison (1966) in *Thais lapillus, Littorina littorea, L. littoralis,* and *L. saxatilis*; Micallef (1967) in *Monodonta turbinata, Gibbula umbilicalis, G. cineraria* and *Callistoma zizyphinumi,* Boyden (1972) in *Cerastoderma edule* and *C. glaucum*; Coleman (1973 and 1976) in *Mytilus edulis* and *Modiolus modiolus*; Bannister (1974) in *Patella caerulea* and *P. lusitanica*; Bayne *et al* (1976) in *Mytilus californianus*; Branch and Newell (1978) in *Patella cochlear, P. oculus* and *P. granularis*; Houlihan (1979) in *Cerithidea obtusa, Cassidula aurisfelis* and *Nerita articulata* and Murdoch and Shumway (1980) in six species of chitons.

Coleman (1973) observed low rates of respiration in *Mytilus edulis* during exposure to air and correlated this reduction in metabolism of *M. edulis* to the saving of energy and food reserves. However, Kuenzler (1961), Houlihan (1979) and Griffiths (1981) made it clear that aerial respiration also plays a significant role in meeting the energy demand of the animals during aerial exposure when there is the occurrence of neap tides. Further investigations on the study of energy budget of these animals during aerial exposure are in progress.

Acknowledgements

References

Bannister J V 1974 The respiration in air and in water of the limpets *Patella caerulea* and *Patella lusitanica*; *Comp. Biochem. Physiol.* **A49** 407-411

Bayne B L, Bayne C J, Carefoot T C and Thomson R J 1976 The physiological ecology of *Mytilus californianus* Conrad: Adaptations to low oxygen tension and air exposure; *Oecologia* **22** 229-256

Bertalanffy L von 1957 Quantitative laws in metabolism and growth; *Q. Rev. Biol.* **32** 217-231

Branch G M and Newell R C 1978 A comparative study of metabolic energy expenditure in the limpets *Patella cochlear, P. oculus* and *P. granularis*; *Mar. Biol.* **49** 351-361

Coleman N 1973 The oxygen consumption of *Mytilus edulis* in air; *Comp. Biochem. Physiol.* **A45** 393-402

Coleman N 1976 The aerial respiration of *Modiolus modiolus*; *Comp. Biochem. Physiol.* **A54** 401-406

Davies P S 1966 Physiological ecology of *Patella*: The effect of body size and temperature on metabolic rate; *J. Mar. Biol. Assoc. U.K.* **46** 647-658

Fisher P H, Duval M and Raffy A 1933 Etudes sur les echanges respiratoires des littorines; *Arch. Zool. Exp. Gen.* **74** 627-634

Goulden C H 1962 *Methods of statistical analysis* (Bombay: Asia Publishing House) pp.467

Griffiths R J 1981 Aerial exposure and energy balance in littoral and sublittoral *Choromytilus meridionalis*; *J. Exp. Mar. Biol. Ecol.* **52** 231-241

Hemmingsen A N 1960 Energy metabolism as related to body size and respiratory surfaces and its evolution; *Rep. Steno Mem. Hosp. Copenhagen* **9** 7-110

Houlihan D F 1979 Respiration in air and water of three mangrove snails; *J. Exp. Mar. Biol. Ecol.* **41** 143-161

Kuenzler E J 1961 Structure and energy flow of a mussel population in a Georgia salt marsh; *Limnol. Oceanogr.* **6** 191-204

Micallef H 1967 Aerial and aquatic respiration of certain trochids; *Experientia* **23** 52-53

Murdoch R C and Shumway S E 1980 Oxygen consumption in six species of chitons in relations to their position on the shore; *Ophelia* **19** 127-144

Newell R C 1979 *Biology of intertidal animals* (Faversham, Kent, U.K.: Marine Ecological Surveys Ltd) pp.782

Prabhakara Rao Y and Prasada Rao D G V 1981a Effect of body size on the respiration of *Cerithidea (Cerithideopsilla) cingulata* (Gmelin 1790) and *Cerithium coralium* Kiener 1841; *J. Molluscan stud.* (in press).

Prabhakara Rao Y and Prasada Rao D G V 1981b End Products of anaerobic metabolism in *Cerithidea (Cerithideopsilla) cingulata* (Gmelin 1790) and *Cerithium coralium* Kiener 1841; *Can. J. Zool.*

Raffy A 1933 Recherches sur le metabolisms respiratoire des poikilothermes aquatiques; *Ann. Inst. Oceanogr. Monaco.* **13** 263-393

Sandison E E 1966 The oxygen consumption of some intertidal gastropods in relation to zonation; *J. Zool. London* **149** 163-173

Snedecor G W and Cochran W G 1967 *Statistical Methods* (Iowa: The Iowa State University Press) pp.593

Toulmand A 1967 Consommation d'oxygene dans l'air et dans l'eau chez quatre gastropodes du genre *Littorina*; *J. Physiol.* **59** 303-304

Umbreit W W, Burris R H and Stauffer J F 1959 *Manometric techniques* (Minneapolis: Burges Publishing Company)

Widdows J, Bayne B L, Livingstone D R, Newell R I E and Donkin P 1979 Physiological and biochemical responses of bivalve molluscs to exposure to air; *Comp. Biochem. Physiol.* **A62** 301-308

Zeuthen E 1947 Body size and metabolic rate in the animal kingdom with special regard to the marine micro-fauna; *Comp. Rend. Lab. Carlsberg ser. Chim.* **26** 17-161

Zeuthen E 1953 Oxygen uptake as related to body size in organisms; *Q. Rev. Biol.* **28** 1-12