Journal of the
Marine Biological Association of India

ABBREVIATION : *J. mar, biol. Ass. India*

Vol. 21 June & December 1979 Nos. 1 & 2

ON THE OXYGEN CONSUMPTION OF THE ESTUARINE MOLLUSC *MERETRIX MERETRIX* UNDER VARIOUS CONDITIONS*

R. S. DESHMUKH

Department of Zoology, Marathwada University, Aurangabad

ABSTRACT

The oxygen consumption of the clam *Meretrix meretrix* was studied in relation to temperature, body size, oxygen content of water, low salinity, starvation and low tide. The rate of oxygen consumption increased with the rise in temperature from 21.0° C to 35.0° C. The respiratory rate was found to be inversely related to the body size when calculated on the basis of weight. The oxygen consumption was little altered by the oxygen concentration in the medium between 2.5 ml/l and 5.0 ml/l. However, at 1.96 ml/l the rate of oxygen consumption was considerably reduced. There was a decrease in the rate of oxygen consumption with the decrease in salinities between 34.4 ‰ and 24.0 ‰ and an increase in the rate with further decrease in salinities from 24.0 ‰ to 17.2 ‰. A distinct decrease in the oxygen consumption was found when the clams were starved in the laboratory for six days. The oxygen consumption was increased in clams when they were exposed to air from 30 minutes to four hours and then returned to original condition.

INTRODUCTION

UTILIZATION of oxygen is a direct measure of degree of activity, food conversion and heat production in animals. Experiments on the respiration of lamellibranchs under various conditions have been carried out by some investigators. Mitchell (1912) had given oxygen requirements of shellfish. Berkley (1921) studied anaerobic respiration in bivalve molluscs. Nozawa (1929) described the normal and abnormal respiration in oysters. Galtsoff and Whipple (1930) and Ishida (1935) studied the oxygen consumption in oysters. Van Dam (1935, 1954) had investigated the oxygen utilization in *Mya arenaria* and scallops.

Hiscock (1953) measured the oxygen consumption of Australian freshwater mussel *Hyridella australis*, in relation to osmoregulation. Jørgensen (1952) made correlative studies of respiration and pumping rate in some marine filter-feeding invertebrates. Collier (1959) had measured oxygen uptake over the full range of pumping rates of oyster *Crassostrea virginica*. Read (1962) studied the respiration of *Mytilus* and *Brachidontus* as a function of size and temperature. Moon and Pritchard (1970) observed metabolic adaptations in vertically separated populations of *Mytilus californianus*.

* Formed a part of Ph.D. thesis approved by the Marathwada University, Aurangabad, India.

The clam *Meretrix meretrix* is one of the most common bivalves occurring in Kalbadevi Estuary, Ratnagiri, Maharashtra State, India. These clams are economically important for their meat which is of some food value and is also used as fish bait; the shells are used as raw material in the lime industry.

In lamellibranchs the current of water drawn through the inhalent siphon is used for feeding and respiration and the rate of oxygen consumption of animals varies with changes in the environmental conditions. *M. meretrix* being found in the estuarine environment, are naturally subjected to fluctuating environmental conditions which are bound to influence the metabolic rate of these animals. Since no information is available on the respiration of *M. meretrix,* the present investigation is aimed to study the oxygen consumption in relation to temperature, size, oxygen content, salinity, starvation, low tide and diurnal rhythm.

I am deeply indebted to Dr. R. Nagabhushanam, Professor and Head, Department of Zoology, Marathwada University, Aurangabad for valuable guidance and criticisms. I am also grateful to the authorities of Office of Naval Research, Washington, U.S.A. for the financial assistance through a grant NOOO 14-70-C-O. 172.

Material and Methods

All experiments were done on *M. meretrix* collected from Kalbadevi Estuary. Individuals were kept in fresh sea water in large trays in the laboratory and permitted to acclimatise at least for 24 hours before the experiment. In all cases only animals that were in apparent good health and extending their siphons to their maximum extent were used.

The apparatus for the determination of oxygen consumption was similar to that used by Galtsoff and Whipple (1930) on American oyster. Five battery jars, each capable of holding two litres of filtered sea water were bound together on sheet-cork. These jars were covered by a wooden frame bearing five stirring rods running at a speed of 5–10 r.p.s.

Clams were taken from the stocks in the large tray. Then one animal each was transferred to experimental jars containing one litre of filtered sea water. The surface of the water was covered with 2.5 to 3.0 cm layer of liquid paraffin to stop gaseous exchange between the sea water in the jar and atmospheric air as suggested by Galtsoff and Whipple (1930). The clams were allowed to acclimatise to the experimental conditions for 15 minutes. After 15 minutes, the actual experiment was started and the oxygen consumptions was recorded. Usually experiments were performed on one clam at a time. The temperature of the water was recorded at the beginning and at the end of each experiment.

Oxygen was estimated by Winkler's method and each time, the water was siphoned out into a well glass stoppered bottle of 250 ml capacity. The oxygen consumed during the experiment was expressed as the amount of oxygen used by a single *M. meretrix* per gram wet weight per litre per hour.

As the clams remained burried in the sand in the natural habitat, the battery jars were painted black.

After the experiment, the animal was removed from the shell, blotted to remove the excess water and weighed.

Every experiment on the oxygen consumption was based upon 2 to 3 separate determinations.

Experiments and Results

Normal respiration

Four clams of uniform size were taken and their oxygen consumption was determined indi-

vidually. Since it was impracticable to record shell movements concurrently, the clams were observed at frequent intervals and the position of their shells and their behaviour were noted (Table 1). The figures quoted in Table 1 give the oxygen consumption of an animal with shells open or closed for one hour.

TABLE 1. *Oxygen consumption of* Meretrix meretrix *under normal conditions*

Temperature: 29.0 °C, Salinity: 34.4‰, O_2 content: 4.20 ml/l

Specimen	Oxygen uptake ml/l/h/gm wet wt with S.D.	Comments
1	0.362 ± 0.005	Shell open all the time
2	0.373 ± 0.003	Shell open all the time
3	0.278 ± 0.006	Shell open part of time
4	0.152 ± 0.007	Shell closed most of time

When the shell valves remained open part of the time during the period of experiment the oxygen consumption was found to be 0.278 ml/l/h/gm wet weight (specimen 3). When the shell valves were in a closed condition for most of the time, there was a decrease in oxygen consumption *i.e.* 0.152 ml/l/h/gm wet weight (specimen 4). On the other hand, opening or movement of the shell valves increased the consumption to 0.373 ml/l/h/gm wet weight (specimen 2) *i.e.* about 2.5 times that of the shell closed state.

From the results it was evident that the shell closure reduced the activity of the animal.

Similar results have been reported by Hiscock (1953) in Australian freshwater mussel *Hyridella australis* and by Nagabhushanam (1966) in *Martesia striata.*

Effect of temperature on the rate of oxygen consumption

The influence of temperature on the rate of oxygen consumption was measured in the range of 21.0°C. to 35.0°C.

The rate of oxygen consumption at room temperature was first measured. It was found that at 27.0°C the clam consumed 0.371 ml O_2/l/h/gm wet weight as shown in Fig. 1.

In order to see if the rate of oxygen intake differs at a temperature lower than that of the natural environment, the following experiment was performed. Ice-cooled water was added to the bath surrounding the experimental jar so that the temperature of the water in the jar was reduced to about 21.0°C. The results under this lower temperature condition presented in Fig. 1 showed that the rate of oxygen consumption was 0.289 ml/l/h/gm wet weight.

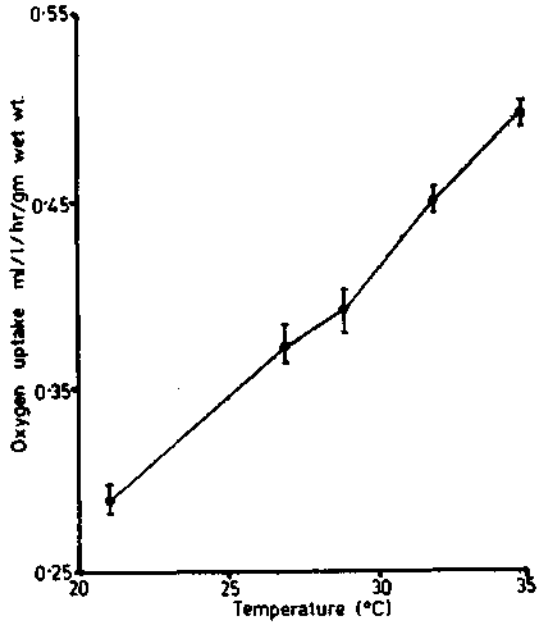

Fig. 1. Showing the influence of temperature on the rate of oxygen consumption in *Meretrix meretrix.*

With a view to see if an increase of temperature of the medium above room temperature had any effect on the rate of oxygen consump-

tion, three jars were maintained at 29.0, 32.0 and 35.0°C. The temperature was controlled by placing the experimental jars in a previously adjusted incubator. The respiratory rate was measured at these temperatures. All the experiments were repeated once and the average results are shown in Fig. 1. It was seen that respiratory rate increased with increase in temperature.

Relation between body size and respiratory rate

It has been well established that the metabolism of animals is considerably influenced by body size. Hence the experiments on the relation of oxygen consumption to the weight of the clams were done using seven different groups of *M. meretrix* varying in their body weights. The oxygen consumption was measured for each size group. Environmental conditions such as salinity, pH, oxygen content and temperature were kept constant. Each experiment was repeated thrice and the results are presented in Table 2.

TABLE 2. *Oxygen consumption of* Meretrix meretrix *in relation to body size*

Temperature: 29.0-29.5°C, Salinity: 34.0‰

Size in mm	Wet weight in gms	Oxygen uptake ml/l/h/gm wet wt with S.D.
24	0.766	0.508 ± 0.002
31	1.578	0.441 ± 0.004
41	2.603	0.403 ± 0.006
43	3.542	0.377 ± 0.005
45	4.562	0.338 ± 0.002
50	5.891	0.285 ± 0.004
57	9.128	0.261 ± 0.003

The results from the Table 2 indicated an inverse relationship between the body weight and the rate of oxygen consumption. The respiratory rate decreased as the body weight increased.

Oxygen consumption as a function of oxygen content

To see the effect of changes in oxygen content of the external medium on the oxygen consumption of *M. meretrix*, the clams were subjected to waters of different oxygen concentrations. Altogether the respiratory rate was measured at five oxygen concentrations and the results are presented in Fig. 2.

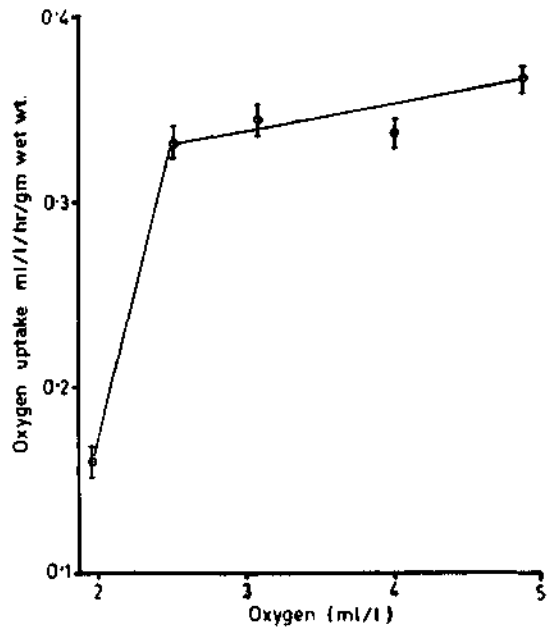

Fig. 2. The effect of oxygen content on the oxygen consumption of *Meretrix meretrix*.

The results of the experiments indicated that the oxygen consumption decreased considerably at the oxygen concentration of 1.9 ml per litre. However it was seen that the rate of oxygen consumption of *M. meretrix* was little altered by the oxygen content of the medium between 2.5 and 5.0 ml/l. These experiments indicate that *Meretrix* can adjust to sudden changes in oxygen content of the estuarine water to some extent.

Influence of salinity on the oxygen consumption

To study the effect of salinity changes on the respiratory rate of *M. meretrix*, observa-

tions were made at five different salinities *viz.*, 34.4‰, 27.5‰, 24.0‰, 20.6‰ and 17.2‰ which were equal to 100%, 80%, 70%, 60% and 50% sea water respectively. These concentrations were prepared by diluting sea water with distilled water. Two experiments at each salinity were conducted and the average from the readings of the two experiments was taken as the oxygen consumed by the clams. The results are shown in Table 3. From the Table it was seen that the rate of oxygen consumption in waters of 20.6‰ and 17.2‰ salinity was higher than in the natural water (salinity 34.4‰). There was a decrease in the rate of oxygen consumption with the decrease in salinities between 34.4‰ and 24.0‰ and an increase in the rate with further decrease in the salinities from 24.0‰ to 17.2‰.

TABLE 3. *The effect of salinity on the oxygen consumption of* Meretrix meretrix

Temperature: 29.0°C, Salinity: 34.4‰

Salinity ‰	Oxygen uptake ml/l/h/gm wet wt with S.D.
34.4	0.363 ± 0.002
27.5	0.353 ± 0.001
24.0	0.313 ± 0.004
20.6	0.371 ± 0.006
17.2	0.389 ± 0.007

Effect of starvation on the respiration

The effect of starvation on the oxygen consumption of *M. meretrix* was studied at room temperature. Five medium sized clams were taken from the stocks in the tray and respiratory rate was measured for individual animals. Then the clams were kept in small trays containing filtered sea water. The water was changed twice a day. The respiratory rates of the same clams were measured individually after 2, 4 and 6 days after starvation.

The results are presented in Fig. 3. It was seen from the figure that the oxygen uptake decreased with starvation.

Oxygen consumption after a period of low tide

It is commonly noticed that during the low tides the clam beds get completely exposed to air and the clams in their natural habitat are subjected to desiccation. To find out the effect of exposure of *M. meretrix* to the atmospheric air on respiration, experiments were conducted in the laboratory.

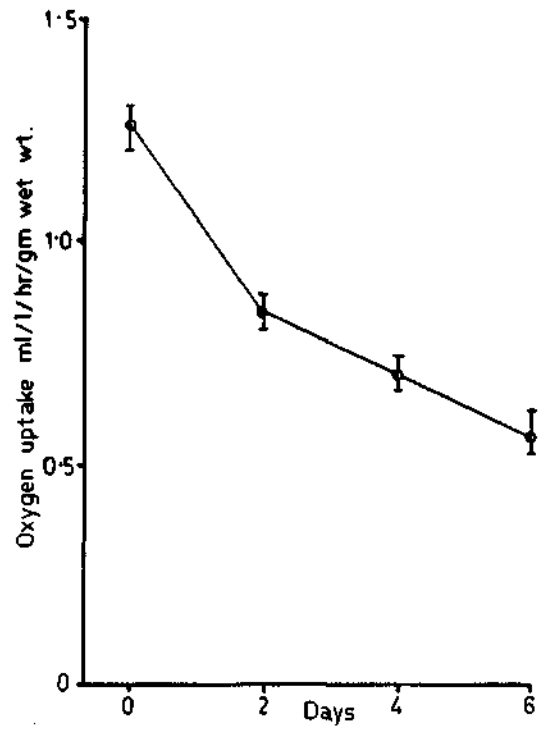

Fig. 3. Oxygen consumption in relation to starvation in *Meretrix meretrix*.

M. meretrix of uniform size were taken from the stocks in the tray. These clams were then exposed to air from 30 minutes to six hours and afterwards they were put back in water and their respiratory rate during the next hour was determined. The results are presented in Fig. 4. The normal rate of oxygen consumption in *Meretrix meretrix* was 0.382 ml/l/h/gm wet weight. This value was used to

determine whether there was an increase in the metabolic rate following exposure periods.

It was seen from the Fig. 4 that the oxygen consumption increased when clams were exposed to air from 30 minutes to four hours and then returned to original conditions. Six hours after return to normal media the oxygen uptake returned to normal rate of 0.372 ml/l/h/gm wet weight.

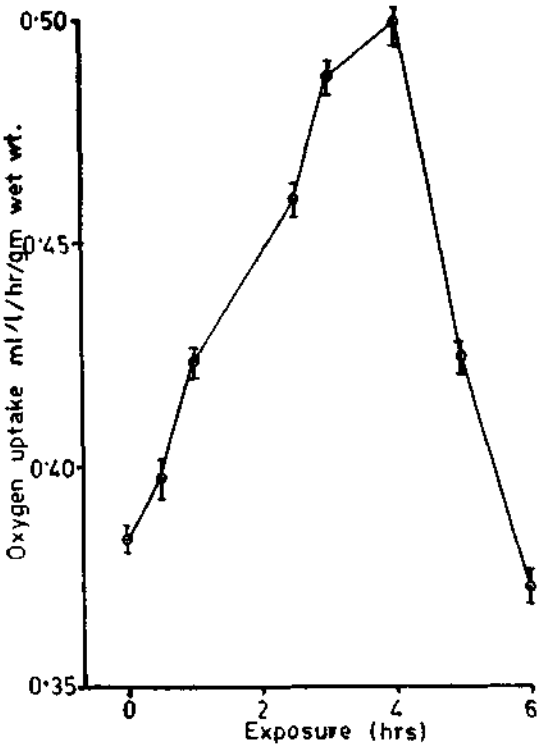

Fig. 4. The oxygen uptake of *Meretrix meretrix* in relation to period of exposure to air.

Discussion

It has been well established that the metabolism of animals is considerably influenced by the body size and temperature of environment. Active rate of metabolism was found to be markedly temperature dependent (Newell, 1966; Newell and Pye, 1971). Changes in temperature, both increase and decrease reduced the oxygen consumption considerably. It was shown by Read (1962) that the rate of oxygen uptake of *Brachidontus demissus plicatulus* increased with temperature upto 32.2°C, the highest temperature tested. He had also demonstrated in *Mytilus edulis* that within the temperature range 3.0 to 20.0°C there was a definite increase in the oxygen consumption with rise in temperature. Nagabhushanam (1966) working on *Martesia striata* showed that there was a very slight increase of oxygen uptake with rise in temperature from 2.40 to 33.0°C.

The results of the experiments on *M. meretrix* showed that the respiratory rate increased with increase in temperature. Similar findings have been reported for other species of lamellibranchs (Galtsoff and Whipple, 1930; Ishida, 1935; Van Dam, 1954; Berg *et al.*, 1962). Newell and Pye (1971) observed that the active rate of oxygen consumption of *Littorina littorea* increased with rise in temperature from 5.0°C. to 25.0°C.

Generally it was observed that weight specific oxygen consumption was higher for small animals when compared with large ones. In the present study it was found that the rate of oxygen consumption decreased as the body weight increased. Von Brand *et al.* (1948) reported that the rate of oxygen consumption in snails was inversely proportional to the size of the animals when calculated on the basis of weight. Similar observations were made by Nagabhushanam (1966) in *M. striata*. Davies (1967) also reported that in *Patella vulgata* the respiration rate of high and low level measured at 15.0°C, was inversely proportional to the size of specimens when calculated on a basis of fresh and dry weight.

The utilization of oxygen in bivalves was little affected by the oxygen tension (Collin, 1921). Dakin and Catherine (1925) reported

in *Anodonta* that the oxygen consumption was independent of oxygen concentration. In the American oyster, oxygen consumption reported by Galtsoff and Whipple (1930) was influenced by oxygen tension only when the latter was 2.5 cc per litre or less. Roch (1931) showed that *Teredo navalis* was satisfied with most different concentrations of oxygen ranging from 9.25 to 0.98 ml/l, and performed normal activities. Van Dam (1954) showed that not too rapid a fall in oxygen content of inspired water, the scollops appeared to be capable of maintaining a normal oxygen uptake down to concentration of oxygen of about 1.0 – 0.5 ml per litre.

It was noticed in the present study that the rate of oxygen consumption was little altered by the oxygen content of the medium between 2.5 ml/l and 5.0 ml/l, but at 1.96 ml/l the rate of oxygen consumption was considerably reduced. Nagabhushanam (1966) observed that *M. striata* was capable of adjusting itself to oxygen concentration ranging from about 2 ml/l to 8.6 ml/l, but at very low levels of oxygen concentration ranging from 0.5 ml/l to 1.0 ml/l the oxygen uptake decreased considerably. Moon and Pritchard (1970) showed that *Mytilus californianus* was a regulator with respect to the relation of external oxygen concentration to oxygen consumption. They observed that there was a relatively narrow zone of respiratory independence.

Salinity has considerable influence on the metabolic activities of animals. Considerable amount of work has been done on the effect of osmotic conditions on the metabolic activities in poikilotherms. Information available on the effect of salinity on oxygen consumption of bivalve molluscs is scanty. It is well known that animals show an increase in metabolism when subjected to environmental stress. Oxygen consumption in *M. striata* was decreased when there was a fall of salinity (Nagabhushanam, 1966). Rao (1958) showed that animals studied by him exhibited low oxygen consumption in their natural medium. *Metapenaeus monoceros* from marine environment showed minimum activity in 100% sea water while prawns from brackishwater environment showed minimum metabolic activity in 50% sea water. In both the groups of prawns the oxygen consumption increased with decrease in salinity below the habitat salinity. In the brackishwater prawns the increase was also effected as the salinity increased to 100% sea water.

It was seen that *M. meretrix* showed minimum oxygen consumption in 70% sea water (salinity 24.0‰) and not in 100% sea water (salinity 34.4‰). Oxygen consumption decreased from 100% sea water to 70% sea water in which minimum activity was noticed. With further reduction in the salinity, the oxygen consumption had increased. Thus, it could be considered that *M. meretrix* was adapted to low salinity, 24.0‰ *i.e.* 70% sea water.

Very little work has been done on the effect of starvation in the poikilotherms. It was observed by Vernberg (1959) in *Uca* and Rajabai (1961) in *Paratelphusa* that the rate of oxygen consumption decreased rapidly in the initial period of starvation and continued to decline at its lower rate but did not attain complete steady level.

The results in the present investigation showed that oxygen consumption of *M. meretrix* decreased with starvation. Similar results were reported by Berg *et al.* (1962) in *Pisidium.* Lomte and Nagabhushanam (1971) working on freshwater mussel *Parreysia corrugata* also reported similar results. They showed that the oxygen consumption was reduced to nearly 50% after starving the animals for 10 days.

Collip (1921) and Van Dam (1935) found that oxygen debt appeared in *Mya* after exposing it to low tide. Increased oxygen consump-

tion in molluscs consequent to exposure to air has been observed by several workers (Mitchell, 1912; Nagabhushanam, 1966; Rao and Kutty, 1968; Moon and Pritchard, 1970; Lomte and Nagabhushanam, 1971) and has been taken as due to the oxygen debt accumulated during the rapid exposure and subsequent rapid increase in respiration on immersal into the water.

The wood-boring bivalve mollusc *M. striata*, when exposed to air from 30 minutes to four hours and then returned to original condition consumed more oxygen. However, seven hours after return to normal media the oxygen uptake returned to normal rate (Nagabhushanam, 1966). The results in the present investigation agree with those obtained by Nagabhushanam (1966). Oxygen debt appeared when *M. mererix* were exposed during low tide and it was gained during the first few hours of the subsequent aerobic period when they were returned to normal conditions.

References

Berg, K., P. M. Jonasson and Ockelmann 1962. The respiration of some animals from the profundal zone of a lake. *Hydrobiologia*, **19**: 26-39.

Berkley, C. 1921. Anaerobic respiration in some molluscs. The relation of anaerobic respiration to glycogen. *Jour. Biol. Chem.*, **46** (3): 579-599.

Collier, A. 1959. Some observations on the respiration of the American oyster *Crassostrea virginica*. *Inst. mar. Sci.*, **6**: 92-108.

Collip, J. B. 1921. A further study of the respiratory processes in *Mya arenaria* and other marine molluscs. *J. Biol. Chem.*, **49**: 297.

Dakin, W. J. and M. G. Catherine 1925. The oxygen requirements of certain aquatic animals and its bearing upon the source of food supply. *Brit. J. Exp. Biol.*, **2**: 293.

Davies, P. S. 1967. Physiological ecology of *Patella* II. Effect of environmental acclimation on the metabolic rate. *J. Mar. biol. Ass. U. K.*, **47**: 61-74.

Galtsoff, P. S. and D. V. Whipple 1930. Oxygen consumption of normal and green oysters. *Bull. U. S. Bur. Fish.*, **46**: 489-508.

Hiscock, I. D. 1953. Osmoregulation in Australian freshwater mussels. II. Respiration and its relation to osmoregulation in *Hyridella australis*. *Aust. J. Mar. Freshw. Res.*, **4** (2): 330-342.

Ishida, S. 1935. On the oxygen consumption of the oyster *Ostrea gigas* under various conditions. *Sci. Rep. Tohoku. Univ. Ser.*, **4** (10): 619-638.

Jørgensen, C. B. 1952. On the relation between water transport and food requirements in some marine filter-feeding invertebrates. *Act. physiol. scand.*, **5**: 297-304.

Lomte, V. S. and R. Nagabhushanam 1971. Studies on the respiration of the freshwater mussel *Parreysia corrugata*. *Hydrobiologia*, **38** (2): 239-246.

Mitchell, P. H. 1912. The oxygen requirements of shellfish. *Bull. U. S. Bur. Fish.*, **32**: 207-222.

Moon, T. W. and A. W. Pritchard 1970. Metabolic adaptations in vertically separated populations of *Mytilus californianus*. *J. exp. mar. Biol. Ecol.*, **5**: 35-46.

Nagabhushanam, R. 1966. On the oxygen consumption of the wood-boring mollusc *Martesia striata*, under various conditions. *Proc. 2nd All India Congr. Zool.* (1962), **2** : 154-159.

Newell, R. C. 1966. The effect of temperature on the metabolism of poikilotherms. *Nature, Lond.*, **212**: 426-428.

——— and V. I. Pye 1971. Quantitative aspects of the relationship between metabolism and temperature in the winkle *Littorina littorea*. *Comp. Biochem. Physiol.*, **38B**: 635-650.

Nozawa, A. 1929. The normal and abnormal respiration in oyster *Ostrea circumpicta*. *Sci. Rep. Tohoku. Imp. Univ., Ser.*, **4**: 259.

Rajabai, K. G. 1961. Studies on oxygen consumption in tropical poikilotherms. VI. Effect of starvation of the oxygen consumption of the freshwater field crab *Paratelphusa* sp. *Proc. Ind. Acad. Sci., B.* **54**: 276-280.

Rao, K. P. 1958. Oxygen consumption as a function of size and salinity in *Metapenaeus monoceros* from marine and brackishwater environments. *J. Exp. Biol.*, **35**: 307-313.

RAO, S. R. AND M. N. KUTTY 1968. Resistance to desiccation and oxygen debt in wedge clams. *Proc. Symp. mollusca, Mar. biol. Ass. India., Cochin,* **2**: 595-606.

READ, K. R. H. 1962. Respiration of the bivalve molluscs *Mytilus edulis* and *Brachidontus demissus plicatulus* as a function of size and temperature. *Comp. Biochem. Physiol.,* **7**: 89-101.

ROCH, F. 1931. Observations on the ecology and physiology of *T. navalis. Marine Piling Inv., New England Commt., Second Prog. Rep.,* 1935-36:249.

VAN DAM, L. 1935. On the utilization of oxygen by *Mya. J. Exp. Biol.,* **12**: 86.

———— 1954. On the respiration of scallops. *Biol., Bull.,* **107**: 192.

VERNBERG, F. I. 1959. Studies on the physiological variation between tropical and temperate zone fiddler crabs of the genus *Uca.* II. Oxygen consumption of whole animals. *Ibid.,* **117**: 163-184.

VON BRAND, T., M. O. NOLEN AND E. R. MANN 1948. Observations on the respiration of *Australorbis grabratus* and some other aquatic snails. *Ibid.,* **95**: 199-213.