in May to 25.00% in August. Occasionally, during monsoon, the salinity of the coastal waters dropped to 15% for a few hours. In this connection, it seems that the shifts observed in the osmotic concentration of E. holthuisi appear to be of adaptive significance for survival during the sudden changes in salinity of the medium.

The hermit crab, Diogenes bicristimanus, at Waltair coast maintained its body fluid concentration hypotonically in sea water of 30% and greater salinities while hypertonicity in 15% and lesser salinities. Isotonicity between the external medium and body fluid was established in the salinities from 20 to 30%.

The behaviour of E. holthuisi was found to be similar to this anomuran crab. Bethe recorded an initial increase in the body weight with increase in dilution in the opisthobranch mollusc, Aplysia sp. When transferred from normal sea water (100%) into 50% sea water, Aplysia regained its original weight within 6 to 10 hr but in 75% sea water it returned to its original weight in 4 to 5 hr. On the contrary, Nerita virens required 60 hr to come back to its initial body weight when transferred from 100% sea water to 60% sea water, whereas in 40% sea water, it required 100 hr to return to its original body weight. In the present investigation it was found that E. holthuisi kept in 25.6% salinity recovered its original weight in about 64 hr but in 18.1% salinity initial body weight of E. holthuisi was restored within 112 hr. Though in 12.8% salinity, E. holthuisi displayed a general decline in body weight after initial rapid gain, it did not regain its original body weight. This may be because of fatigue or failure of the volume regulatory mechanism which seems to be operative in E. holthuisi kept in 25.6 and 18.1% salinities.

References

Respiration of the Wedge Clam Donax cuneatus

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Normal respiration was markedly reduced due to shell closure mechanism in D. cuneatus. In reduced salinities, perhaps due to the inhibition of ciliary activity of gills, the normal rate of respiration was decreased. With rise in temperature up to 34°C res­piratory rate increased and declined sharply at 38°C. Oxygen debt occurred during the exposure period which was subsequently recovered in the first 6 hr after reimmersion in sea water. Inverse variation of weight specific oxygen consumption was noticed with the size of the clam. After 8 days of starvation 50% reduction in the normal respiratory rate occurred. In slight acidic medium the respiration was more whereas in slight alkaline medium it was less compared to in normal pH of the sea water. A distinct diurnal rhythm of respiration was observed; the clam consumed more oxygen at noon and less at midnight.

SEVERAL environmental factors are known to influence the respiration of bivalves and many studies on the marine bivalves of Indian coasts have been made. The present study has been undertaken on the wedge clam, D. cuneatus, a marine intertidal bivalve occurring in abundance along the Ratnagiri coast.

D. cuneatus was collected from the sandy intertidal area of Ratnagiri Bay. The clams were brought to the laboratory and kept in fresh sea water of matching salinities. Adults of equal size (6-17 mm) were used in the experiments. Oxygen consumption was determined using the apparatus similar to Galtsoff and Whipple's. Oxygen content in sea water was determined using Winkler's technique.

Normal oxygen consumption — Clams under laboratory conditions did not show any regular pattern in valve opening. Hence it was necessary first to find out the rate of oxygen uptake in accordance with the differential pattern in valve opening of the clams at normal laboratory temperature and habitat salinity. The results are presented in Table 1.

Effect of low salinity — To study the effect of low salinity on the rate of oxygen uptake, the clams were subjected to low salinity gradations for 3 hr

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before the start of the experiment. The normal salinity of sea water was 33.4%. Salinities tested were 33.4, 28.39, 23.38, 20.04 and 16.7%. At each salinity, to find out the oxygen consumption all other physiological conditions were kept constant. The results (Fig. 1a) show that the rate of oxygen uptake decreased progressively with increase in dilution of sea water.

Effect of temperature — Four batches of clams were subjected to different temperatures (24°, 31°, 34° and 38°C) and their rate of oxygen uptake was determined. The clams were subjected to experimental temperatures by gradual alteration and they were allowed to remain at these temperatures for 1 hr before their oxygen uptake was determined. Simultaneously a control experiment was performed at the normal laboratory temperature (28°C). The rate of oxygen uptake increased with rise in temperature up to 34°C and beyond this temperature the rate decreased as the temperature increased to 38°C (Fig. 1b).

Effect of exposure to atmospheric air — Clams were removed from the stock aquaria and exposed to atmospheric air for 7 hr on sunny and windy days. The clams were taken out at the intervals of 1 hr and kept in normal sea water. As soon as they extended their siphons, the rate of oxygen uptake was determined (Fig. 2a). Normal rate of oxygen uptake was 0.7 ml/g/hr/litre. Oxygen uptake increased with increase in the exposure period up to 6 hr after which it returned to normal rate by 7th hr of exposure (Fig. 2a).

In relation to body size — This experiment was conducted on 4 different size groups of clams. For each size group, during the experimentation, all physiological conditions were kept constant. The results show that the total oxygen consumption increased with increasing size (Table 2) whereas weight specific oxygen consumption decreased with increase in size (Fig. 2b).

Effect of starvation — Five clams were taken and their oxygen uptake was determined on the 1st day. At the same time, 25 clams were removed from the stock aquaria and kept in filtered sea water at normal laboratory temperature. From the 2nd day, the clams were kept in double filtered sea water and the water was changed twice a day. The clams extended their siphons much more compared to their extension in normal sea water so as to have large amount of sea water to pass through the gills for getting food. Oxygen uptake using 5 clams in each experiment was measured each day for a period of 8 days. The results (Fig. 3) show that the normal rate of oxygen uptake was 0.717 ml/g/hr/litre and it started declining gradually; about 50% decrease occurred by the end of 8th day of starvation. This indicated that the total metabolism decreased with progressive starvation.

Effect of pH — Rate of oxygen uptake was measured at 3 different pH values. Normal pH of the sea water was 7.3. Highest rate of oxygen uptake was at pH 6.5 and lowest at pH 7.9 oxygen uptake at pH 6.5, 7.3 and 7.9 respectively was 0.775 ± 0.008, 0.713 ± 0.012 and 0.668 ± 0.005 ml/g/hr/litre.

Diurnal rhythm — To see whether there is any diurnal rhythmicity in the rate of oxygen uptake of this wedge clam, oxygen uptake was measured at different times of the day. The results (Table 3) show a distinct diurnal rhythmicity in the oxygen uptake. The clams consumed maximum oxygen at noon and minimum at midnight.

![Fig. 1](image1.png)  
**Fig. 1** — Effect of (a) low salinity and (b) temperature on the oxygen uptake in *D. cuneatus*.  

![Fig. 2](image2.png)  
**Fig. 2** — Oxygen uptake (a) after a period of low tide and (b) in relation to body size (weight specific) of *D. cuneatus*.  

![Table 1](table1.png)  
**Table 1** — Oxygen uptake of *D. cuneatus* under normal conditions (Temperature 30°±0.5°C, Salinity 33.4%).

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Oxygen uptake (ml/g/hr/litre)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7 ± 0.017</td>
<td>Valves open part of the time</td>
</tr>
<tr>
<td>2</td>
<td>0.692 ± 0.006</td>
<td>Valves open most of the time</td>
</tr>
<tr>
<td>3</td>
<td>0.507 ± 0.009</td>
<td>Valves open part of the time</td>
</tr>
<tr>
<td>4</td>
<td>0.325 ± 0.014</td>
<td>Valves closed most of the time</td>
</tr>
</tbody>
</table>
A close relationship exists between the amount of oxygen consumed by an organism and metabolic processes such as growth, repair of tissue, excretion, digestion and osmoregulation. Furthermore, any act, which results in the performance of mechanical work, increases oxygen uptake. The bivalves in a shell-opened condition do not always require continuous and variation in the values of rate of oxygen uptake between individuals may be related to the duration of valve opening. In the present study it has been observed that the shell-closing mechanism considerably reduced the rate of oxygen uptake in Donax cumnatus. Similar reduction in the oxygen uptake due to shell closure was observed earlier.

It has long been known that the oxygen uptake of animals is affected by a change in the temperature of the external medium. It is now well established that the standard metabolism of animals is relatively independent of acute temperature change while the active rate of metabolism is highly temperature dependent. In Brachidontes demissus, piicatilus the rate of oxygen uptake increased with rise in temperature up to 32°C but in Mytilus edulis this increase in oxygen consumption was only recorded with the rise in temperature from 3°C to 20°C. Such increase in oxygen uptake was also noted in Meretrix meretrix wherein the oxygen uptake increased with rise in temperature from 21°C to 35°C. Generally, the rate of metabolic processes of any poikilothermic animal increases almost to the extreme upper limit of the temperature at which this animal performs its activities and beyond this limit it decreases as the lethal temperature approaches. This concept is well exemplified by D. cumnatus of the present study in which the oxygen uptake increased with rise in temperature from 24°C to 34°C and then decreased sharply at 36°C.

It is found that metabolism of animals increases when they are removed from their normal salinity and placed in a stress medium. At several instances it was noted that the decrease in salinity of the external medium caused increase in metabolism of animals and many hypotheses have been put forth to explain this increased metabolism. However, the results of the present study show that the rate of oxygen uptake constantly decreased with progressive decline in the salinity in D. cumnatus. The decrease in the rate of oxygen uptake at low salinities was also observed in Martesia striata.

The importance of time course of physiological adaptation in rate functions was emphasized where-in commonly 3 periods could be recognized: an initial shock reaction lasting seconds or minutes, a stabilized rate of minutes or hours and an acclimation of compensation over a period of days or weeks. Van Winkle studied the ciliary activity of isolated gill tissues of 4 bivalves and noticed direct inhibition of the gill cilia by reduced salinity. Bayne studied the time course of acclimation of oxygen uptake in Mytilus at reduced salinity, wherein he observed decline in the rate of oxygen uptake immediately after the reduction of salinity due to direct inhibition of gill cilia, and then within 6-8 hr recovery of the oxygen uptake rate occurred.

Within 24-36 hr oxygen uptake had returned to nearly the values recorded before dilution of the water. In the present study clams were kept in reduced salinities only for 2-3 hr before they were used for experiments. It may, therefore, be possible that in D. cumnatus the gill cilia may directly be inhibited by reduced salinity causing decline in the rate of oxygen uptake. In other words, a primary inhibition of oxygen uptake might have occurred when the clams were subjected to low salinities for a few hours before the experiments.

The bivalve body is oxygenated only by the continuous circulation of water and therefore it is interesting to study the reaction of a bivalve to periodic exposure to atmospheric air. Intertidal species such as Mytilus californianus are subjected to periods of hypoxia during shell closure at low tide. Increased oxygen uptake in bivalves as a result of anoxic stress during the period of exposure has been observed by several authors and the accumulated oxygen debt has been found to be subsequently recovered on reimmersion in sea water. Bivalves have the ability to trap water in the mantle cavity as the tide recedes, which might serve as a store of oxygen for respiratory activities during periods of exposure. In the present study, it has been observed that the oxygen debt occurred during the period of exposure and was recovered.

### Table 2 - Total Oxygen Uptake in D. cumnatus

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Average wt (g)</th>
<th>Oxygen uptake (ml/hr/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>0.025</td>
<td>0.0195 ± 0.0115</td>
</tr>
<tr>
<td>12</td>
<td>0.07</td>
<td>0.0515 ± 0.0175</td>
</tr>
<tr>
<td>16</td>
<td>0.14</td>
<td>0.0985 ± 0.0295</td>
</tr>
<tr>
<td>20</td>
<td>0.242</td>
<td>0.1596 ± 0.028</td>
</tr>
</tbody>
</table>

### Table 3 - Diurnal Rhythm of Oxygen Uptake in D. cumnatus (Temperature 24.5-30°C, Salinity 32%) (a)

<table>
<thead>
<tr>
<th>Time of observation (hrs)</th>
<th>Oxygen uptake (ml/g/hr/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0600</td>
<td>0.695 ± 0.015</td>
</tr>
<tr>
<td>1200</td>
<td>0.715 ± 0.009</td>
</tr>
<tr>
<td>1800</td>
<td>0.688 ± 0.008</td>
</tr>
<tr>
<td>2400</td>
<td>0.654 ± 0.012</td>
</tr>
</tbody>
</table>
back in the first 6 hr of reimmersion in water, thus increasing the respiration for the first 6 hr. Accumulation of oxygen debt during exposure in D. cuneatus and D. gaha was observed and the tendency to increase oxygen uptake with an increase in the duration of exposure was similar in both the species.

It is generally agreed that the weight specific oxygen uptake is higher for smaller animals when compared with larger ones, measured at a given temperature and determined for animals of a given species or for closely related ones. The results of present investigation are in accordance with this general concept and show that the rate of oxygen uptake decreases as the body weight increases. Similar inverse relationship between the rate of oxygen uptake and size was observed in other bivalves.

Decrease in metabolic rate has been reported in a number of starved poikilotherms. Reduction in the rate of oxygen uptake of Pachygrapsus crassipes due to starvation was observed in the initial stages and later the rate reached a steady level. Three-fifths reduction in the initial value of oxygen uptake of the limpet, Ancylus, was recorded after 96 hr of starvation. In Paratellina, the rate of oxygen uptake decreased rapidly in the initial period of starvation; the rate continued to decline further but did not attain a complete steady level. In D. cuneatus starvation affected the oxygen uptake and there was 50% reduction in the metabolic rate after a starvation period of 8 days. The earlier findings support this view.

Fishes are directly affected by changes in pH of the external medium. The change in respiratory rate of fishes is supposed to be due to the influence of pH of the external medium on the alkaline reserves of the blood. In Martesia striata, very little change in the oxygen uptake occurred with change in pH. In the present study it has been observed that the maximum rate of oxygen uptake occurred at pH 7.5 and the minimum at pH 8.2. In Katelystia opima similar results were obtained, whereas the maximum rate of oxygen uptake was at pH 6.8 and minimum at pH 8.4.

A distinct diurnal rhythm occurred in the respiration of oysters; these oysters consumed more oxygen in the late morning and early noon than at midnight. Certain environmental factors such as low and high tide, temperature, light, darkness, etc., initiate the rhythms at first which later become persistent. D. cuneatus also shows diurnal rhythmicity in oxygen uptake. Rate of oxygen uptake was maximum at noon and minimum at midnight.

The authors wish to thank Prof. R. Nagabhushanam for his interest.

References

Factors Affecting Fluid Losses in the Oyster, Crassostrea cuneata

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In slucked oysters in which the shells were removed with no injury to mantle and pericardium lost fluids and body weight (58-7% of the original) while those with injury to the mantle and pericardium lost 66-27% of the original body weight. In both the cases most of this fluid loss took place within 15 min after shucking. It was observed that the oysters must be free to open and close their shells for weight and volume regulation. Oysters, prevented completely from opening and closing their shells, lost weight both in and out of water due to the secretion of body fluids. Oysters were found to have a limited ability to osmoregulate and showed no weight regulation when subjected to various dilutions of sea water.

OSS of body fluid is a problem of great economic concern to the oyster industry. Investigation on the physiology of body fluid in the oyster, C. cuneata, a commercial species found along the west coast of India, is being carried out. Among the several factors that have been considered are losses due to injury and to heat shock. The present report summarizes experiments on the extent of loss of body fluid in C. cuneata which were shucked in winter of 1974.

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