RESPIRATORY METABOLISM

The energy expended by most animals to meet the demands of the various metabolic activities due to the changing external environment, can be measured in terms of oxygen uptake since the rate of oxygen uptake is influenced by many extrinsic and intrinsic factors. The metabolism of poikilothermic animals as measured by the oxygen consumption is a highly complex physiological process subject to the influence of a number of factors such as body size, nutritional stage, temperature, salinity, pH, oxygen tension etc. of the medium. All these factors collectively and individually influence metabolism of the animal.

Temperature is the principal controlling factor influencing the metabolic rate of poikilotherms (Krogh, 1916; Marshall et al., 1935; Fox, 1936; Edwards and Irving, 1943; Edwards, 1946; Mac and Bullock, 1954; Dehnel, 1960; Armitage, 1962; McFarland and Pickens, 1965; Newell and Northcroft, 1967; Barnes and Barnes, 1969; Newell and Pye, 1971; Kottaiah and Rajabai, 1972; Percy, 1974). Edwards and Irving (1943) observed in Emerita talpoida that the oxygen consumption was increased with temperature but was brought back to normal value when the original temperature was restored. Gopalakrishnan (1957) measured the oxygen consumption of Metapenaeus monoceros in relation to environmental conditions. Dehnel (1960) investigated the combined
effect of temperature and salinity on respiratory metabolism of the crabs, *Hemigrapsus oregonensis* and *H. nudus*. Wiens and Armitage (1961) studied the oxygen consumption of the crayfish *Orconectes immunis* and *O. nais* in relation to temperature.

It has been pointed out that in a number of euryhaline invertebrates, the rate of oxygen consumption varies inversely to the change in salinity of the external medium (Schlieper, 1930; Krogh, 1939; Hopkins, 1943). Kreps (1929) showed that the rate of oxygen intake of *Balanus crenatus* was not affected by changes in salinity between 12% to 30% and below 12% salinity, the rate was decreased considerably. The rate of oxygen consumption of *Carcinus maenas* increased considerably in hypotonic media (Schwabe, 1933). Similar results were obtained by Flemister and Flemister (1961) on *Cypoda albicans*. Gross (1957) in *Nca* and Dehnel (1960) on *Hemigrapsus* studied the effect of salinity on respiration. Jones (1974) reported the effect of low salinity on the oxygen consumption of *Idotea neglecta* and *I. emarginata*.

Another environmental parameter which has been given considerable attention is the effect of pH on respiration. Detailed studies on this aspect have been made only in fishes (Powers, 1921, 1930, 1932). Helff (1928) found that changes in pH had no effect on oxygen consumption of
the crayfish *Cambarus immunis*. Marshall et al. (1935) observed that in *Calanus finmarchicus* the effect of pH changes between 8.08 and 7.40 on the oxygen consumption was negligible. Copleakhshan (1957) studied the effect of pH on the oxygen consumption of *Metapenaeus monoceros*. Ramasurthi (1962) showed that in the crab *Paratalphusa* respiration varied directly with the pH.

The relationship between dissolved oxygen concentration of the external medium and the rate of oxygen consumption in Crustacea have been studied by few workers (Krogh, 1916; Hiestand, 1931; Marshall et al., 1935; Van Weel et al., 1954; Wiens and Armitage, 1961; Teal and Carey, 1967; Gamble, 1970). Wiens and Armitage (1961) determined the oxygen consumption of *Oreconetes immunis* and *O. nasus* in response to oxygen saturation. Teal and Carey (1967) recorded the oxygen consumption at different oxygen levels. McMahon et al. (1974) studied respiratory responses to long term stress in crayfish *Oreconetes virilis*.

It is well known that one of the most important factors influencing the metabolism of an animal is its own body size and the metabolism varies directly with the body size. Zeuthen (1947, 1953) made a detailed investigation on the relationship between body size and metabolic rate of the crab *Pachygrapsus crassipes*. Hemmingsen (1960) reviewed the literature on the effect of size on metabolic
rate of poikilotherms. Young (1963) found that the oxygen consumption decreased with increase of size in *Pagurus*.

Very little work has been done on the effect of desiccation on respiration in Crustacea. Gross (1955) had shown oxygen consumption to decrease as a function of desiccation in *Pachygrapsus crassipes*. Foster (1971) registered the effect of desiccation on respiration in barnacles.

Studies on the effect of starvation on the metabolism of Crustacea are very few; these studies show that oxygen consumption of the animals decreases rapidly in the initial periods of starvation reaching a steady level in some (Roberts, 1957) and continues to decline at slower rate but no complete attainment of steady level in others (Rajabai, 1961, 1963).

The effects of toxic substances like copper and mercury salts on various marine animals have been studied as a part of the antifouling investigation conducted by the marine corrosion sub-committee of British Iron and Steel Research Associations (Barnes, 1946). Barnes and Stanbury (1948) studied the effect of copper and mercury salts on *Nucula spinipes*. Pyefinch and Mott (1948) have studied the sensitivity of barnacles and their larvae to some poisons. The oxygen consumption of *Marinogammarus maximus* in relation to some poisons has been studied by Hinter (1950).
Dowden (1960) studied the cumulative toxicities of some inorganic salts to *Daphnia magna*. Costa (1965, 1966) worked on the responses of *Gammarus pulex* and its oxygen consumption to various toxic substances.

Various investigations have been made on the toxicity of different insecticides on the insect pests of agricultural importance. Atef et al. (1972) worked on the chemical control of some scale insects of orange trees using three insecticides. Mathen et al. (1972) studied the effects of immediate toxicity of six insecticides used for the control of the adults of *Stephanitis typicus*, a pest of coconut foliage. Thimmaiah et al. (1972) worked on insecticidal control of cutworm *Agrotis ypsilon* on tobacco and Verma et al. (1972) studied the chemical control of hairy caterpillar, *Euproctis fraterma* on jujube using various insecticides. Sathiamma et al. (1972) published a note on the effect of insecticides on the slug caterpillar, *Contheyla rotunda*.

The effects of insecticides have been studied in crustaceans such as *Caridina weberi* (Costa, 1970), *Gammarus lacustris* (Sanders, 1971). Naqvi and Denzel (1970) in *Palaemonetes kadiakensis* studied the insecticide resistance. Sanders (1971) studied the toxicity of pesticides on *Gammarus lacustris*. Costa (1970) studied the effects of some insecticides on the heart beat of
Caridina pristis. All these studies are limited to the mortality effect of the insecticides on crustaceans.

The present investigation was aimed to study the oxygen consumption of Caridina rajadhari in relation to different environmental factors like temperature, salinity, pH, oxygen tension, desiccation, starvation, toxic substances and insecticides.

**MATERIAL AND METHODS**

Caridina rajadhari were collected from Kham river near Aurangabad. On arrival to the laboratory, prawns were kept in shallow water tanks containing tap water. The water was changed daily and the animals were fed on few bits of water weeds. The temperature of the water varied between 25°C to 28°C during the period of the studies. Both male and female (but not berried) prawns were used in the experiments. Oxygen consumption was measured by standard Winkler's method. The quantity of oxygen consumed was calculated in relation to unit wet weight of the animals and the value thus obtained was expressed as rate of oxygen consumption in ml. per gram wet weight per hour and the standard deviation of the arithmetical mean was calculated.

A constant flow apparatus, similar to the one used by Gopalkrishnan (1957) was set up. The apparatus is shown in figure 1. By this means water was circulated at a
uniform rate through the respiration chamber containing the test animals. Tube ' h ' prevents the water in the second aspirator ' B ' from rising above a certain level and as the first aspirator ' A ' is at a higher level than ' B ' and as the tube ' g ' leading water from ' A ' to ' B ' is stouter than ' j ' the water level in the aspirator ' B ' is kept steady. This ensures a uniform speed for the flow of water through the respiration chamber as all the parts of the apparatus are clamped to fixed positions.

The rate of flow of water was calculated by measuring the volume of water collected in the receiver during a period of one hour. As it was necessary to run the experiment without interruption for four hours and also to analyse two samples after each hour the receiver jar ' E ' was taken away at the end of the hour and an identical one was substituted. As the temperature of the flowing water in the respiration chamber ' C ' was to be maintained constant for a fairly long period, a wide mouthed thermosflask was used as the bath ' D '. The size of the respiratory chamber ' C ' is such that the test animals kept in it just fit into it and only a minimum amount of movements are possible.
**RESULTS**

Effect of temperature on Oxygen Consumption.

Five prawns of uniform size were inserted into the respiratory chamber under water, taking care not to damage the body and appendages. The oxygen consumption was measured at three different temperatures i.e. 18°C, 25°C, and 35°C.

Ice-cooled water was added to the bath surrounding the respiratory chamber so that its temperature varied between 13.5°C to 16.5°C. In this manner the temperature of the outflowing water from the respiratory chamber was brought to about 18°C. The experimental data is presented in Table 1 and Fig. 2. The average rate of oxygen consumption was found to be 0.116 ± 0.004 ml/g/hr. The oxygen consumption at room temperature was 0.309 ± 0.006 ml/g/hr. In order to see the effect of elevated temperature on oxygen consumption of Caridina, the temperature of the respiratory chamber was so adjusted that the outflowing water indicated the temperature of 35°C. The results were summarized in Table 1. Fig. 2. It was seen that at higher temperature the respiration was high in Caridina.

2) Oxygen consumption in relation to salt concentration of the medium.

The effect of salt concentration on respiration of
### Table 1

Oxygen consumption of *Caridina rajadhari* in relation to temperature.

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>O₂ ml./g./hr./l.</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>0.116 ± 0.004</td>
</tr>
<tr>
<td>25</td>
<td>0.309 ± 0.006</td>
</tr>
<tr>
<td>35</td>
<td>0.609 ± 0.010</td>
</tr>
</tbody>
</table>

### Table 2

Oxygen consumption of *C. rajadhari* in relation to salinity

Temperature of the medium 24 - 25°C  
**pH**: 6.9 - 7.0

<table>
<thead>
<tr>
<th>Salinity of the experimental medium (in % NaCl)</th>
<th>O₂ ml./g./hr. ± S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without acclimation</td>
</tr>
<tr>
<td>F.W.</td>
<td>0.236 ± 0.012</td>
</tr>
<tr>
<td>0.1</td>
<td>0.339 ± 0.004</td>
</tr>
<tr>
<td>0.3</td>
<td>0.341 ± 0.001</td>
</tr>
<tr>
<td>0.5</td>
<td>0.259 ± 0.011</td>
</tr>
</tbody>
</table>
**Caridina rajadhari** was studied by passing the animals through different grades of pure sodium chloride solutions. The concentrations used were 0.1%, 0.3% and 0.5%.

The first set of observations were made using the prawns from the stock aquaria containing tap water. After measuring the oxygen consumption in normal tap water, the animals were transferred to the respective salt solutions, for measuring the respiratory rate. The same procedure was continued up to 0.5% salt concentration. Temperature and pH of the medium were kept constant throughout the experiment. All the experiments were repeated and the results were given in Table 2 and Fig. 3.

**Rate of oxygen consumption under normal tap water.**

The first set of observations were made using prawns that had been kept under tap water. This medium is similar to the environmental medium. It could be seen from Table 2 that average oxygen consumption of *Caridina rajadhari* was $0.236 \pm 0.012$ ml/gram/hr.

**Rate of oxygen consumption at 0.1% NaCl.**

In this experiment, 0.1% pure sodium chloride solution (isotonic with 2.86% sea water) was used. Table 2 gives the data obtained in this experiment. Care was taken to keep all the experimental conditions like temperature, pH and oxygen content constant and identical with those of
earlier experiments. The results obtained showed that the rate of oxygen consumption at 0.1% sodium chloride solution was $0.339 \pm 0.004$ ml/gr/hr.

**Rate of oxygen consumption at 0.3% NaCl.**

Experiments conducted with prawns that had been kept in the medium of 0.3% sodium chloride (isotonic with 8.57% sea water) indicated that average rate of oxygen consumption by the animals increased to $0.341 \pm 0.001$ ml/gr/hr.

**Rate of oxygen consumption at 0.5% NaCl.**

Further experiments were conducted with the medium of 0.5% NaCl solution (isotonic with 14.29% sea water). There was a sudden decrease of oxygen consumption from 0.341 to 0.259 ml/gr/hr. The results of the present experiment are presented in Table 2.

**Rate of oxygen consumption after acclimation to various salt solutions.**

In order to see the rate of oxygen consumption at various grades of salt solutions after acclimation, the prawns were acclimated for 10 days to the media of normal tap water, 0.1%, 0.3% and 0.5% NaCl. The experiment started with the normal tap water, through various grades
of sodium chloride solutions in an ascending order. 
The experimental data presented in Table 2 showed that 
there was a considerable reduction in the rate of oxygen 
consumption in all the experimental media studied.

The relation between the rate of oxygen consumption 
and the salinity of the medium for both normal and with 
acclimated was presented in Fig. 3. From the figure it 
is seen that the rate of oxygen consumption in media 0.1 
and 0.3 % NaCl is higher than in the natural medium and 
0.5 % NaCl. A reduced rate of oxygen consumption but with 
same trend was also seen in the prawns acclimated to above- 
mentioned media.

Effect of pH on oxygen consumption.

In order to find out the influence of hydrogen ion 
concentration on the rate of oxygen consumption of Caridina, 
the respiratory rates of the prawns were determined at 
five different pH media ranging from 5.5 to 9.5. The low 
PH values were obtained by adding dilute HCl whereas it 
was raised by adding dilute NaOH. The respiratory rate 
of the prawn was not changed much between 6.2 to 6.9 but 
at high as well as at low pH the oxygen consumption was 
considerably reduced. The pH of the river water from where 
the animals were collected was normally found to vary 
between 6.5 to 7.5. Hence the animals exhibited normal
### Table 3

Effect of pH on oxygen consumption of *Caridina rajadhari*.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>pH of the medium</th>
<th>Average oxygen consumed in ml./g./hr./l.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5</td>
<td>0.128 ± 0.003</td>
</tr>
<tr>
<td>2</td>
<td>6.2</td>
<td>0.211 ± 0.009</td>
</tr>
<tr>
<td>3</td>
<td>6.9</td>
<td>0.221 ± 0.004</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
<td>0.173 ± 0.001</td>
</tr>
<tr>
<td>5</td>
<td>9.5</td>
<td>0.113 ± 0.004</td>
</tr>
</tbody>
</table>

### Table 4

Unit metabolism of *C. rajadhari* in relation to body weight.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Weight of prawns in grams</th>
<th>O2 ml./g./hr./l.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.300</td>
<td>0.501 ± 0.002</td>
</tr>
<tr>
<td>2</td>
<td>0.500</td>
<td>0.411 ± 0.004</td>
</tr>
<tr>
<td>3</td>
<td>0.850</td>
<td>0.391 ± 0.007</td>
</tr>
<tr>
<td>4</td>
<td>1.050</td>
<td>0.266 ± 0.071</td>
</tr>
<tr>
<td>5</td>
<td>1.400</td>
<td>0.210 ± 0.005</td>
</tr>
</tbody>
</table>
respiratory rate at pH 6.2 to 6.9. The low rate of oxygen consumption may be due to the fact that these pH values are lethal to the animals. As the pH reached alkalinity, the respiratory rate decreased markedly, the lowest being at pH 9.5 (Table 3, Fig. 4).

Influence of oxygen tension on respiration.

The effect of changes in oxygen content of the external medium on oxygen consumption of Caridina rajadhami was studied by subjecting the animals to waters of different concentrations. Altogether oxygen consumption was measured at three different oxygen concentrations and the results are presented graphically in Fig. 5. The results of the experiment indicate that the rate of oxygen consumption of Caridina is reduced considerably at very low level of oxygen tension. (1.0 ml/L).

Oxygen consumption in relation to size.

The metabolism varies according to body size. The experiments on the relation of oxygen consumption to the weight of the prawns were done using animals belonging to five different size groups. From Table 4 and Fig. 6, it may be concluded that the respiratory rate is inversely proportional to the size of prawns when calculated on the basis of unit weight.
Effect of desiccation on respiration.

To find the effect of exposure to atmospheric air on *Caridina*, experiments were conducted in the laboratory. The respiratory rates were measured after the exposure to air for 0, 2, 4 and 6 hours. Twenty prawns were taken from the stock aquarium and the moisture adhering to the body of the animal was removed with blotting paper. The rate of oxygen consumption of five prawns was immediately measured after putting them back to freshwater. The remaining 15 prawns were divided into three sets; one set was exposed for two hours to the atmospheric air and then they were put back in the water and oxygen uptake was determined. The second set was exposed for 4 hours to air while the third set was kept for six hours. After the experimental desiccation each set was put back into the fresh water and the rate of respiration was calculated. The results are presented in Fig. 7. It is seen from the figure that the rate of oxygen consumption increases as the time the animals exposed to atmospheric air is increased.

Effect of starvation on oxygen consumption.

To find out the effect of starvation on respiration, the following experiments were conducted in the laboratory. Thirty prawns were taken from the stock aquarium. The rate of oxygen consumption of five animals was immediately measured. The remaining twenty prawns were divided into
Table 5

Effect of starvation on oxygen consumption of Caridina rajadhari.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>No. of days starved</th>
<th>O2/ml./gm./hr./L.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>0.304 ± 0.001</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.271 ± 0.004</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.260 ± 0.009</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>0.211 ± 0.010</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>0.150 ± 0.008</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>0.143 ± 0.006</td>
</tr>
</tbody>
</table>
sets and kept for starvation for 2, 4, 6, and 10 days and the rate of respiration was calculated. The results are presented in Table 5 and Fig. 8. It was seen that the rate of oxygen consumption decreased as the time of starvation was increased.

**Effect of chemicals on oxygen consumption.**

To find out the effect of various chemicals on the rate of oxygen consumption, solutions of toxic substances were made with concentration in which the animals were tested to survive at least for ten days. It was found that the oxygen consumption of *Caridina rajadhari* was considerably decreased in all experimental solutions when compared with that of the controls indicating the effects of toxins. (Table 6).

**Effect of insecticides on the oxygen consumption.**

In order to investigate the effect of insecticides on the oxygen consumption of the prawns, the experiments were conducted with five insecticide solutions of different concentrations. The results are presented in Table 7. It was found that the rate of oxygen uptake was decreased considerably in all the experimental solutions except DDT and bleaching powder, when compared to the controls.

**DISCUSSION**

Earlier studies on temperate and arctic animals showed that in many forms increase or decrease in temperature
Table 6

Effect of toxic substances on oxygen consumption of *G. rajadhari*.

<table>
<thead>
<tr>
<th>Toxic substance</th>
<th>0₂/ml/gm/hr/L Control group</th>
<th>0₂/ml/gm/hr/L Experimental group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper sulphate</td>
<td>0.192 ± 0.009</td>
<td>0.161 ± 0.001</td>
</tr>
<tr>
<td>Ammonium oxalate</td>
<td>0.166 ± 0.003</td>
<td>0.102 ± 0.015</td>
</tr>
<tr>
<td>Potassium oxalate</td>
<td>0.164 ± 0.006</td>
<td>0.112 ± 0.001</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>0.189 ± 0.003</td>
<td>0.163 ± 0.004</td>
</tr>
<tr>
<td>KMnO₄</td>
<td>0.199 ± 0.001</td>
<td>0.193 ± 0.0006</td>
</tr>
</tbody>
</table>
### Table 7

**Effect of insecticides on oxygen consumption of C. rajadhari.**

*Temperature of water 26 - 28°C.*

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Insecticide</th>
<th>Concentration of medium in %</th>
<th>Mean values of oxygen consumed ± S.D. (ml./g./hr./l.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>1</td>
<td>Dimecron</td>
<td>0.0004</td>
<td>0.122 ± 0.008</td>
<td>0.194 0.0003</td>
</tr>
<tr>
<td>2</td>
<td>Endrin</td>
<td>0.0005</td>
<td>0.073 ± 0.0005</td>
<td>0.100 0.010</td>
</tr>
<tr>
<td>3</td>
<td>Thiodan</td>
<td>0.0005</td>
<td>0.079 ± 0.0006</td>
<td>0.104 0.0002</td>
</tr>
<tr>
<td>4</td>
<td>Bleaching Powder</td>
<td>0.10</td>
<td>0.137 ± 0.0015</td>
<td>0.129 0.001</td>
</tr>
<tr>
<td>5</td>
<td>D.D.T.</td>
<td>0.10</td>
<td>0.168 ± 0.0003</td>
<td>0.137 0.017</td>
</tr>
</tbody>
</table>
of the external medium above and below the normal was accompanied by increase or decrease in the rate of oxygen consumption. Marshall et al. (1935) observed that the rate of oxygen consumption was increased with the rise in temperature in copepod, *Calanus finmarchicus*. Identical results were obtained for *Carcinus maenas* (Caprao, 1939). Fox (1936) and Fox and Wingfield (1937) indicated that the crustaceans collected from Plymouth showed a higher rate of oxygen consumption than related species from the colder zone of Sweden. The rate of oxygen uptake of *Astacus fluviatilis* was shown to be constant for the range 5° to 15°C. (Schlieper, 1930) although earlier studies by Brunov (1911) indicated that the rate was about four times higher at 15°C during the period of six to ten hours. Gopalkrishnan (1957) found the rate of oxygen consumption in *Nepenaeus monoceros* to be increased with the rise in temperature. Vernberg (1959) working on *Uca* found that the rate of oxygen consumption was increased with increase in temperature. Dehnel (1960) working on crabs *Hemigrapsus oregonensis* and *H. nudus* showed that summer animals have higher oxygen consumption than winter specimens. Wiens and Armitage (1961) in crayfish, *Orconectes immunis* showed that the rate of oxygen consumption increased with increasing temperature. Sarojini and Nagabhushanam (1963) reported similar results in hermit crab, *Mogopas*. Rajabai (1964) also found that summer *Baryla* consume more oxygen than winter crabs.
The above brief discussion indicates that the metabolic response to temperature is not a generalised phenomenon but it varies depending upon the species, nature of acclimation and previous thermal history.

The results of the experiments on Caridina rajadhari showed that with the decrease in temperature the oxygen consumption also decreased. This was in agreement with the results reported earlier in the literature on other Crustacea. The decrease in oxygen consumption in the lower temperature range may be due to the fact that the tropical animals live near the maximum limits of temperature tolerance (Mayer, 1913) so that any further decrease in temperature of the external medium than that of the animal is accustomed to, reduces the rate of metabolism considerably.

It is known that where animals with osmoregulatory powers adjust themselves to varying salinity conditions of the external media, energy is expended and it is natural to expect corresponding variation in oxygen consumption (Beadle, 1931; Lowenstein, 1935, Krogh, 1937; Hopkins, 1949). Lowenstein (1935) observed that in lower salinities below 25% the rate of oxygen consumption of Gammarus chevreuxi was increased. Carcinus maenas showed increased respiratory rate in a dilute medium. However, Schwabe (1943) was unable to record any differences in the respiratory metabolism of the Eriocheir in sea water of
salinities 15% and 32%. and also fresh-water. Kepa (1929) observed that in Balanus respiration was independent of salinities from 12% to 35% but below 12% the rate was decreased. The absence of changes in the rate of oxygen consumption in some instances may be due to other related physiological processes like ionic regulation. Krogh (1939) suggested that the amount of energy spent during osmoregulatory ability might not be sufficiently large to show marked changes in respiratory rates. Simmons and Knight (1973) observed that the oxygen consumption in Neomysis intermedia generally decreased as salinity increased from 1% to 70% sea water. In the present investigation on Caridina rajadhari it was found that the highest oxygen consumption was found in 0.1 and 0.3% NaCl solutions (isotonic with 2.86 and 3.57% sea water) but at higher concentration (0.5% NaCl, that is, isotonic with 14.29% sea water), the respiratory rate was decreased. Similar observations were made by Lofts (1956) in Palaemonetes varians and Pamipatirao (1958) in Metapenaeus monoceros.

It is well known that the changes in hydrogen ion concentration are, in many cases, of importance to animal life. The pH changes in fresh water are greater compared to those in sea water (Powers, 1930). Helff (1928) showed that the rate of oxygen consumption in Cambarus immaculatus was not dependent on the changes in pH of the external medium. A similar observation on the respiration
of the copepod Calanus was made by Marshall et al. (1935). However, Hiestand (1931) had shown that low pH increased oxygen consumption in dragonfly larvae. Powers (1921, 1930) found that the fishes are effected directly by increase or decrease in pH of the medium. A similar observation on oxygen consumption of the hermit crab Mogenes macrostigma was made by Sarojini (1966). Gopalkrishnan (1957) studied the oxygen consumption of Metapenaeus monoceros and observed that the rate of oxygen consumption was not directly effected by the change in pH. However, in Caridina oxygen consumption was affected by pH. Maximum oxygen consumption was observed at pH 6.9 at room temperature while it decreased at very acidic and alkaline pH.

It has been shown that crustaceans from different habitats show different metabolic responses when oxygen tension decreases or increases. It was shown that in Carcinus maenas and Scyllarus latus the rate of oxygen consumption did not differ over a wide range of oxygen tension of the medium (Henze, 1910). The same author concluded that in several cold blooded animals the rate of metabolism was independent of the oxygen tension of the environment. The prawns Palaemonetes was able to tolerate changes in oxygen tensions of the medium till the latter is lowered to about 50% air saturation (Amberson et al., 1924). Similarly the crayfish Cambarus was able to maintain
a constant rate of respiration till the saturation was
reduced to about 25% (Heff, 1928; Hestand, 1931).
The copepod Calanus was apparently unaffected by higher
oxygen tension of water, but in concentration below 3 ml/l.,
respiratory adjustment was not possible (Marshall et al.
1935). A study of seven species of crabs from different
habitats (Van Weel et al, 1954) demonstrated that the
rate of oxygen uptake of a mud dwelling crabs was indepen-
dent of ambient oxygen tensions until a low level was
reached; at this point, the respiration patterns become
oxygen dependent. Species from well aerated waters, however,
exhibited an oxygen-dependent response over a wide range
of oxygen tension. All species showed an increase in
percentage of oxygen utilization concentrations less than
2.5 ml of oxygen/litre. This response was interrupted as
an attempt by the organism to ensure a minimum amount of
oxidation. Similarly, fiddler crabs, Uca pugilator and Uca
pugnax living in burrows in sandy-muddy substrates may
experience low oxygen tension when the tide is in. These
crabs continue to consume oxygen in low oxygen tensions
while Sesarma cinereum stop respiring at a somewhat higher
values (Teal and Carey, 1967). In Cardina the consump-
tion of oxygen was normal up to 5 ml/l but below that the
respiratory rate had decreased considerably.

Several workers have stressed the importance of the
dependence of metabolism on body size when making inter-
and intra-specific comparison of crustaceans (Edwards and Irving, 1943 a, b; Zeuthen, 1953; Robers, 1957). Vernberg (1959) observed in *Uca pugnax* and *U. rapax* that $Q_{10}$ varied with size and temperature levels. Wiens and Armitage (1961) found that *Oreconetes immunis* had a higher rate of metabolism in all sizes of animals. Further, they discovered that the differences in metabolic rate were greater and were constant as body weight was increased. Gampati and Prasad-Rao (1960) and more recently Prasadn Rao and Gampati (1969) have shown that the relationship of weight specific respiration rate to body size varies significantly at 25°C in the barnacles, *Balanus tintinnabulum* and in *Balanus amphitrite*. In the present study on *Cardina*, it was found that the rate of oxygen consumption decreased as the body weight increased up to a certain level.

Collip (1921) and Van dam (1935) found that oxygen debt appeared in *Hya* after exposing it to low tide. Nagabhushanam (1957) obtained similar results in *Nartasia*. Gross (1955) working on *Pachygrapsus crassipes* found that the oxygen consumption decreases as a function of desiccation. He also found that short term desiccation is believed not to be deleterious. Similar observations made by Sarojini (1966) in *Moganas bicristimamus* where the oxygen consumption decreased as the tide the animal exposed to air was increased. In the present investigation on *Cardina* the results are in agreement with the earlier
findings. The oxygen consumption decreased as the time of exposure to air was increased.

Roberts (1957) observed that the rate of oxygen consumption was affected by starvation in the initial stages and then reached a steady level. Vernberg (1955) on Uca and Rajabai (1961, 1963, 1964) on Paratelphusa hydromorus found that decline in respiration was slower after initial rapid decrease, but did not attain complete steady level. Aldrich (1974) working on Cancer pagurus observed that although both fed and starved crabs are governed by the same rhythm, the average elevation of fed rates, compared with starved ones, is explained by the greater average amplitude of cycles in fed crabs. Kotaiah and Rajabai (1972) have shown that starvation is generally known to influence the oxygen consumption directly in different animals, and in Paratelphusa hydromorus the oxygen consumption was decreased with a progression of the starvation period. The present study on Caridina showed that there is a decrease in the rate of oxygen consumption with starvation.

Heavy metal salts constitute a very serious type of pollution in fresh water because being stable compounds, they are not readily removed by oxidation, precipitation or other pressure and affect the activity of the animals. (Costa, 1966). While working on Gammarus pulex, he found decreased oxygen consumption in all the toxic substances
like lead nitrate, zinc sulphate, copper sulphate and
mercuric chloride. Hunter (1950) found that the toxicity
of the copper sulphate, mercuric chloride to *Marinamarmarina
marina* differs widely. He found that the copper sulphate
lowers the oxygen consumption considerably and mercuric
chlordide did not affect too much. In the present study on
*Caridina* the rate of oxygen consumption decreased considera-
bly in all toxic solutions. American workers on anti-
feuling problems have published results supporting the
view that copper retards vital processes through inactiva-
tion of essential enzymes (Clark, 1947).

It has been observed that the organophosphate
insecticides are more toxic than chlorinated hydrocarbon
insecticides (Sanders, 1971). Sanders (1971) came to
the above conclusion while testing various insecticides,
herbicides and fungicides against crustacean, *Gammarus
lagunensis*. Endrine proved to be most toxic to *Palaemonetes
kadiakensis*, when compared with other insecticides like
DDT, methylparathion, parathion, sevin etc. (Naqui and
Densal, 1970). Ataf et al. (1972) observed that the
carbaryl was less effective in control of some insects of
orange trees in Egypt. In the present investigation, it
was found that endrine was most toxic to the prawns while
Dimecron and Nuvacon (organophosphate insecticides) are
less toxic than thiodon and carbaryl. However, KMnO₄, DDT and bleaching powder have not shown any remarkable effect on the oxygen consumption of the prawns.
SUMMARY

1. A study on the rate of oxygen consumption of *Caridina rajaehari* in relation to temperature, salinity, pH, oxygen tension, desiccation, starvation, toxic substances and insecticides was made.

2. The rate of oxygen consumption was increased with rise in temperature from 18°C to 32°C.

3. The rate of oxygen consumption was high at 0.1 and 0.3% NaCl solutions (isotonic with 2.36 and 3.57% sea water) but the rate was low at 0.5% NaCl (isotonic with 14.29% sea water).

4. The respiratory rate of *Caridina rajaehari* remained unchanged between pH 6.2 to 6.9. High pH (9.5) as well as low pH (5.5) caused a decrease in the rate of oxygen consumption.

5. Oxygen consumption of *C. rajaehari* was reduced considerably at low oxygen tension (1.0 ml/l).

6. The rate of oxygen consumption was found to be inversely proportional to body size when calculated on the basis of unit weight.

7. As the time animals were exposed to air increased, the rate of oxygen consumption was decreased.
8. Oxygen consumption of *C. rajadhari* decreased with progressive starvation.

9. Chemicals exerted toxic effect on the oxygen consumption of *C. rajadhari*. The rate of oxygen consumption was remarkably low when placed in different concentrations of toxic substances like copper sulphate.

10. Prawns consumed very little oxygen when placed in solutions of insecticides. However, in DDT and bleaching powder the rate was increased.
Figure 1.

General scheme of apparatus

A, B = aspirator
C = respiration chamber
D = bath
E = receiver jar
F, K, L = thermometers
H = overflow tube
G, I = supply tubes
J, M = taps
N = layer of liquid paraffin
Fig. 2. Oxygen consumption of *Caridina rajadhari* as a function of temperature.
O2/ml G/Hr/L

Temperature °C.
Fig. 3. Relationship between oxygen consumption of *Caridina rajadhardi* and salinity of the medium.
Before acclimation

After acclimation
Fig. 4. Influence of pH on the rate of oxygen consumption of *Caridina raiadhari*.
Fig. 5. Effect of the oxygen tension on the rate of oxygen consumption in *Caridina rajadhari*.
Fig. 6. Relationship between body weight and rate of oxygen consumption in *Caridina rajadhari*.
$O_2 \text{ ml G. Hr. L.}$

Weight in grams.
Fig. 7. Effect of desiccation on the oxygen consumption in Caridina rajadhari.
Fig. 8. Effect of starvation on the oxygen consumption in *Caridina rajadhani*.
Graph showing the decrease of O₂ ml/G/Hr/L over days.