CHAPTER IV

Respiration

Respiratory apparatus, Oxygen consumption and ventilation frequency.
RESPIRATORY APPARATUS

In the lower Crustacea, especially in the Branchiopoda, the fulfilment of the respiratory needs are supplemented by the thoracic appendages in addition to the body surface. In this subclass, the thoracic appendages are not only locomotary organs but are organs that help in feeding and are also chief respiratory organs. All the thoracic appendages are alike, biramous and setose, as in the general plan described by Dexter (1943). There are one or two pre-epipodites at the base of each appendage but generally fused. The epipodites never have spines. Distally the exopodites and the endopodites having endites, are filamentous with setae and setules.

Baqai (1963) working on Streptocephalus seali and Bernice (1972) on S. dichotomus described the development of thoracic appendage while studying their postembryonic development.

In Streptocephalus dichotomus Baird, the basic structure was similar as described by Dexter (1943). The thoracic appendage appeared from the second larval stage of development. During subsequent stages of development several lobes were added to the ventral side of the appendage to form the exopodite, two lobes at anterior side to form distal epipodite and one preepipodite. The setae produced on the margin of the exopodite and epipodite (one to six) were very few in number, subsequently they increased in number and contained
setules in adult.

In adult, the **exopodite** having a large flabellum consisted of fortyfive setae and the endites of endopodite (one to six) having setae, whereas the epipodite and preepipodites were the membranous structures and are devoid of setae. The preepipodite have cirration around its margin with a botch on its middle.

The thoracic appendages with their exopodites and endopodites, whose function is to bring in a steady current of water over the membranous epipodite and preepipodite, together with the epipodite and preepipodite form the respiratory apparatus of the animal. The preepipodites and epipodites are the main areas of exchange of respiratory gases.

In the studies of respiration and respiratory mechanism, in fairy shrimps, ventilation frequency measurements have a special significance. Some observations were, therefore, made on this aspect along with the observations on the effects of temperature, salinity, pH, oxygen tension and body **size** on oxygen consumption by the animals under laboratory conditions.
PLATE - 8

Theracic appendage - The respiratory apparatus of *Streptocephalus dichotomus.*

**ENDP** : Endopodite
**EPD**  : Epipodite
**EXPD** : Exopodite
**FL**   : Flabellum
**PRPD** : Preepipodite
RESPIRATORY APPARATUS
(Ventral view)

EXPD
FL
DIP
EPD
FRPD

0.5 mm
A wide range of physiological adjustments enable animals to survive as active members of the community in temporary pools of fresh water in tropical and subtropical regions, where they are subjected to quick/drastic fluctuating conditions, are the characteristics of these ecosystems. Basic metabolic environmental interactions are reflected in oxygen utilization. Though a single parameter of oxygen consumption does not reflect the total fitness or otherwise of an organism for a given habitat, the energy expended by most animals to meet the demands of the changing external environments in temporary fresh water ponds can be a significant indicator.

The metabolic rate of the poikilothermic animals is measured in terms of oxygen uptake, which is directly influenced by many intrinsic and extrinsic factors, such as, temperature, salinity, pH, oxygen tension, body size etc.

(1) Temperature:

It is the most important environmental factor influencing the metabolic rate of an animal. Krogh (1914) studied the influence of temperature on the oxygen consumption of different animals. Further contributions were made by Marshall et al. (1935), Fox (1936). Edwards and Irving (1943) observed in Emerita talpoida, that the oxygen consumption increased with temperature but came to normal after restoring the original temperature. Scholander et al. (1953) observed the oxygen
consumption of a number of arctic and tropical cold blooded animals at various temperatures. Gopalkrishnan (1957) studied relation of environmental conditions and the oxygen consumption in *Metapenacus monoceros*. Dehnel (1960) observed the combined effect of temperature, salinity and respiratory metabolism in relation to the oxygen consumption in *Hemigrapsus oregonensis* and *H. nudus*. Wiens and Armitage (1961) working on crayfish *Orconectes immunis* and *O. nais* studied oxygen consumption in response to the temperature. Newell and Northcroft (1967) observed that the standard rate of metabolism of animals was relatively independent of acute temperature changes while active rate of metabolism was highly temperature dependent. Sarojini (1966) working on *Diogenes bicristimanus*, Chinnaya (1968) on *Caridina*, Gokhale (1970) on *Petrolisthes lamarkii*, Diwan (1972) on *Barytelphusa cunicularis* found that the relation between oxygen consumption and temperature was reciprocal.

(2) **Salinity:**

It has been shown that in a number of invertebrates the rate of oxygen consumption varies inversely to the changes in salinity of the external medium (Schlieper, 1929; Korg, 1939; Hopkins, 1949). Schlieper (1929) found that the changes in salinity of the medium resulted in an increased oxygen consumption in *Carcinus maenas*.

The rate of oxygen consumption was increased considerably in hypotonic media (Schwabe, 1933). Similar results were
obtained by Flemister and Flemister (1951) in *Ocypode quadrata*; Gross (1957) in *Uca* and by Dehnel (1960) in *Hemigrapsus nudus* and *H. oregonensis*. *Mytilus edulis* consumes less oxygen when exposed to changed salinity (Kinne, 1963).

(3) **pH**.

Available literature suggests that very few contributions have been made by the physiological ecologists about the effect of pH on oxygen consumption in Crustacea. Helff (1928) observed that the oxygen consumption was unaffected by the changes in pH in Crayfish *Cambarus immunis*. Marshall et al. (1935) working on *Calanus finmarchicus*, observed negligible effect on oxygen consumption in pH range of 8.08 to 7.40. Gopalkrishnan (1957) on *Metapeneous monoceros* and Sarojini (1966) on *Diogenes bicristimatus* studied the relationship of pH and oxygen consumption.

(4) **Oxygen concentration/tension**:

The relationship between dissolved oxygen concentration of the external medium and the rate of oxygen consumption in many aquatic invertebrates have been studied by several workers and it was concluded that this relationship is variable (Krogh, 1916; Hiestand, 1931; Marshall et al., 1935). Wiens and Armitage (1961) studied the relationship of oxygen consumption with oxygen saturation in *Orconectes immunis*. The tubicolous crustaceans were studied by Gamble (1970). Diwan (1972) studied this relationship in the tropical fresh water crab *Barytelphusa cunicularis*. 
(5) **Body size:**

The rate of metabolism varies directly with the body size. Zeuthen (1947) made detailed investigations on the relationship in the animal kingdom, about the metabolic rate and the body size. Roberts (1957) in Crab *Pachygrapsus crassipes* and Young (1963) in *Pagurus* observed that the oxygen consumption decreases with the body size. Chinnayya (1968) on *Caridina*, Gokhale (1970) on *Petrolisthes* and Diwan (1972) on *Barytelphusa* also worked on the same aspect.

In the present investigation, an attempt has been made to study the oxygen consumption of *Streptocephalus dichotomus* Baird, in relation to the temperature, salinity, pH, oxygen tension and body size.

**MATERIALS AND METHODS**

The fresh water fairy shrimps *S. dichotomus* used for the present investigation were collected from the fresh water ponds around Aurangabad and Amalner. They were acclimated to the laboratory conditions for two days using pond water before the experimentation. The water temperature varied between 27°C to 28°C during the experimental period. Daily fluctuations in the temperature were between 22°C to 27°C. Water was changed daily.

The oxygen consumption was measured by standard Winkler's method as modified by Stickland and Parson (1968). The quantity of oxygen consumed was calculated in relation to unit wet weight
of the shrimps and the values obtained were expressed as ml. O$_2$/gm./hour/litre at N.T.P. In the different experiments, standard deviations were calculated.

Fairy shrimps of similar size and weight were used for the experiments. The experiments were performed in glass jars used as respiratory chambers. Weighed shrimps were introduced in the jars having 100 ml. of pond water. They were allowed to acclimate for fifteen minutes before taking the initial readings. A thick layer of liquid paraffin was added in order to prevent the aeration during the period of experiment. The experiment was performed for two hours, without interruption.

The pH determinations of the water samples were made with Elico's pH meter. To get the required pH, dilute HCl (0.2N) or NaOH (0.2N), (as per the required situation) was added to the pond water (Saroha, 1964).

The oxygen tension of the water was lowered by boiling the normal water (Jones, 1952) and the required oxygen tension was obtained by oxygenating the boiled water after cooling. The dissolved oxygen was estimated by the standard Winkler's method.

The required salinity was obtained by adding NaCl to the pond water and estimations were made by titrating with silver-nitrate solution (Jhonson et al., 1964).
EXPERIMENTS AND RESULTS

1) Influence of temperature and oxygen consumption:

The fresh water fairy shrimps of 20 mm. average length were weighed and introduced in the experimental respiratory jars. The initial reading was taken after fifteen minutes during which period the animals were acclimated. The higher temperatures were maintained by using thermostats. The lower temperatures were maintained by keeping the ice-blocks around the respiratory jars.

The different temperatures selected for study were 17°C., 22°C., 27°C., 32°C. and 38°C. The pond water temperature recorded at the beginning of experiment was 27°C. ± 0.5°C. During the experiments to study the effects of temperatures on oxygen consumption, all other factors viz., salinity, pH, oxygen tension and osmotic concentration were kept constant so as to make sure that whatever changes in the oxygen consumption were only due to the effect of temperature. The influence of temperature on oxygen consumption has been presented graphically (Fig. 7).

It was observed in *S. dichotomus* that the oxygen consumption increases with increase in temperature.

2) Influence of salinity on oxygen consumption:

The effect of salinity on the oxygen consumption of *S. dichotomus* was studied by exposing them to different grades of sodium chloride solutions. The media were prepared with
NaCl and pond water of salinities varying from 0.1% to 0.5%. The first set of observations were made using the shrimps under the pond water. After measuring the oxygen consumption in normal pond water they were transferred to the set of 0.1% salinity. Temperature (27°C. ± 0.5°C.) and pH (7.5) were kept constant throughout the experimental period. The same procedure was repeated for 0.2%, 0.3% and 0.4% salinities. The experiments were repeated thrice and the mean values for oxygen consumption in different salinity media were calculated and presented graphically (Fig. 8). It was observed that the rate of oxygen consumption decreases with increase in salinity.

3) Influence of oxygen tension on oxygen consumption:

The experiments were performed to observe the relationship of oxygen tension in the medium and oxygen consumption by _S. dichotomus_. The respiratory rate was measured at six different oxygen concentrations ranging from 1 ml./litre to 5 ml./litre oxygen. The results are presented graphically (Fig. 10). These observations clearly indicate that as the oxygen tension increased, the rate of oxygen consumption was considerably reduced.

4) Influence of pH on oxygen consumption:

For the study of effect of hydrogen ion concentration on the respiratory rate of _S. dichotomus_ nine different pH were used. The pH of the water was increased or decreased
by the addition of dilute NaOH or dilute HCl respectively. The pH of the water tested were 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5 and 9.0. During the experimental period, temperature and oxygen concentration were kept constant. The oxygen consumption was calculated at each pH and results are graphically presented (Fig. 9).

The respiratory rate remained unchanged at pH 5.0 and 5.5, but with increasing pH the oxygen consumption was considerably increased up to pH 7.5 at which it was maximum. Further increase in pH reduced the oxygen consumption. At pH 9.0 it was the same as at pH 5.0 to pH 5.5. The pH of the habitat water was usually between 7.0 and 8.0.

5) Influence of body size on the rate of oxygen consumption:

In order to find out the effect of body weight three different sets of experiments were conducted using three different groups of S. dichotomus with different body lengths namely 15 mm., 20 mm. to 30 mm., 30 mm. and more.

Equal number of animals were used and the environmental conditions such as temperature, pH. and oxygen were kept constant. Each experiment was repeated thrice and the results are graphically presented (Fig. 11). It was observed that oxygen consumption (O2 ml./gm./hour/litre at N.T.P.) decreased with the increase in body size.

**DISCUSSION**

The metabolic compensation to thermal stress has been demonstrated by several authors with reference to several
processes like oxygen consumption, development, growth, heart beat etc. (Bullock, 1955). Earlier literature on temperate and arctic animals shows that, decrease or increase in the temperature of the external medium corresponded to the rate of oxygen uptake. In the crab *Carcinus maenas* increase in the rate of oxygen consumption was directly proportional to the increase in temperature (Capraro, 1939). Edward (1946) observed that the crab *Emerita* became less active in lower temperature. As the temperature of the external medium increased, rise in oxygen consumption was noticed by Edward and Irving (1943), in *Emerita talpoida*. Vernberg (1959) working on *Uca* found that the rate of oxygen consumption was increased with increase in temperature. Similar observations were made by Wiens and Armitage (1961) on crayfish *Orconectes immunis*, Sarojini and Nagabhushanam (1968) on hermit crab *Diogenes*, Nagabhushanam and Chinnayya (1968) on *Gelasimus*, Chinnayya (1968) on *Ceridina* and Diwan and Nagabhushanam (1972) on *Barytelphusa*.

The results of the present experiments on *Streptocephalus dichotomus* showed that with the decrease in temperature, the oxygen consumption also decreased and with the rise in temperature of the external medium, the rate of oxygen consumption increased up to the limit of tolerance. This is in agreement with the results reported earlier in the literature on other crustacea.

The decrease in oxygen consumption in lower temperature range may be due to the fact that tropical animals live near
their maximum limits of temperature tolerance Mayer (1918). So that any further decrease in temperature of the external medium than that to which the animal is accustomed tend to reduce the rate of metabolism considerably. On the other hand it was also recorded by Schlieper (1930) on Astacus that the rate of oxygen consumption remained constant for the range 5°C to 15°C. Crisp and Rits (1968) stated that at higher temperatures many of the warm acclimated animals become more active. Newell and Pye (1970) while working on Littorina littorea and Mytilus edulis concluded that the temperature range over which metabolism compensation occurs is controlled by acclimation temperature.

The brief discussion indicates that the metabolic response to temperature varies depending upon the species, nature of acclimation and previous thermal history.

Several workers have recorded their observations on the metabolic response of poikilotherms to osmotic stress. Lawenstein (1935) working on Gammarus observed increased rate of oxygen consumption when salinity was lowered. In Carcinus maenas Schawbe (1933) showed that in dilute medium the respiratory rate increases. In S. dichotomus the highest rate of oxygen consumption was observed in 0.3% salinity. At higher concentration like 0.4% respiratory rate was decreased. In natural habitat water the respiratory rate was lower than that was observed in 0.3% NaCl solution.

Similar observations were recorded by Lofts (1956) in Palaemonetes varians, Pampapathi Rao (1958) in Metapenaeus -
monoceros, Ramamurthy (1962) in Paratelphusa sp., Madammohan Rao and Rao (1962) in Sesarma and Lepas, Chinnayya (1968) in Caridina, Diwan and Nagabhushanam (1972) in Barytelphusa - cunicularis. They observed that the animals studied by them exhibited low oxygen consumption in their natural medium.

It is well known that pH is an important factor that affects the metabolic rate of the fresh water animals. Earlier, Helff (1928) found that the rate of oxygen consumption in Cambarus immunis was unaffected by the changes in pH of the external medium. A similar observation was recorded by Marshall et al. (1935) in Calanus. But Hiestand (1931) in dragonfly larvae and Powers (1930) in fishes found that the animals are directly affected by increase or decrease in pH of the external medium. The change in the respiratory rate is supposed to be due to the influence of pH of the external medium and consequently on the alkali reserve of the blood. Identical observations were recorded by Sarojini and Nagabhushanam (1968) in Diogenes, Chinnayya (1968) in Caridina - weberi and Diwan (1972) in Barytelphusa cunicularis.

The present study on S. dichotomus shows the effects of different pH on the rate of oxygen consumption. The rate of oxygen consumption was found to be maximum at pH 7.5, whereas on either side of this pH the respiratory rate was decreased. It appears that extreme ranges of pH on either side are lethal to the animal under study. Similar observations were made by Saroja (1964) in the earthworm Lampito mauritii, Chinnayya (1968) in Caridina weberi and Diwan (1972) in Barytelphusa.
The change in oxygen tension also has an important effect on the rate of oxygen consumption of *S. dichotomus*. The results of the experiments show that low oxygen concentration reduces the rate of oxygen consumption which may be due to the fact that below the respiratory limit the animals are unable to tolerate low oxygen tension Helff (1928). The above observations with *S. dichotomus* agree with the previous records on other crustaceans.

In *Diogenes* below 4 ml./litre the respiratory rate decreases above which the animal was able to adjust its respiratory rate (Sarojini and Nagabhushanam, 1968). It was, however, recorded in *Carcinus maenas* and *Scyllarus latus* by (Henze, 1910) that the rate of oxygen consumption did not differ over wide ranges of oxygen tensions of the medium. He further observed that in several cold blooded animals the rate of metabolism is independent of the oxygen tension of the environment. The results are at variance with these observations.

Amberson et al. (1924) in *Palaemonetes*, Helff (1928) and Hiestand (1931) in *Cambarus*, Weymouth et al. (1944) in *Pugettia*, recorded that at higher concentration the rate of respiration was unaffected but at lower levels it decreased markedly. Whereas Amberson et al. (1924) in *Homarus americanus*, *Limulus polyphemus* and *Callinectes sapidus*, shows that the rate of oxygen consumption is directly dependent on oxygen tension of the medium. Similar result was also seen
in *S. dichotomus*. In *Cancer* and *Eupagurus*, Moore et al. (1972), recorded that the oxygen tension is directly proportional to the metabolic rate of the animals.

It was observed that the smaller individuals within a species, have a higher metabolic rate per unit weight and time than have larger individuals. Vernberg (1959), in *Uca pugnax* and *Uca rapax* observed that the smaller species have higher metabolic rate than those of larger size which was previously recorded by Edward and Irving (1943) on *Emerita talpoidea*, Zeuthen (1953) on general survey of animal kingdom and Roberts (1957) on *Pachygrapsus crassipes*. Rajabai (1964) working on *Paratelphusa* found that the rate of oxygen consumption increased with the increase in body size.

In the hermit crab *Diogenes*, Sarojini and Nagabhushanan (1968), in the crab *Gelasimus* Nagabhushanan and Chinnayya (1968), in prawn *Caridina* Chinnayya (1968) and in the crab *Barytelphusa*, Diwan (1972), it was noticed that the rate of oxygen consumption decreased as the body weight increased up to certain level and thereafter the oxygen uptake remained more or less constant.

In the present study on *S. dichotomus*, it was observed that the rate of oxygen consumption decreased as the body size increased. It may be due to the fact that changes in the surface area of the respiratory apparatus, may impose limitations on the metabolic rate which is suggested by the fact that with increasing size of animal there is generally a relative reduction in the respiratory area per unit body weight.
VENTILATION AND VENTILATION FREQUENCY

The respiration includes the primary mechanism by which an adequate oxygen supply to the tissues, is ensured. The exchange of gases between the medium and respiratory surface (and blood), by the process of diffusion across the general body surface, is not adequate to bring sufficient oxygen to the tissue. In some aquatic crustaceans, diffusion of gases is supplemented by specially modified areas of the body surface (the thoracic appendages), which are continuously washed by the medium, i.e. either fresh or marine water. In the aquatic forms in addition to the fulfilment of the respiratory needs, the modified devices may be concerned partly with feeding and locomotion. The filter feeders, which are continuous swimmers, have a steady stream of water passing over their body surface. These water-movements over the respiratory surfaces are brought about almost entirely by rhythmic beating of thoracic appendages, particularly in branchiopods, anapsids, etc.

In the aquatic lower crustaceans, the ventilation is brought about by special musculature. The water-movements over gills or other special respiratory devices or surfaces are brought about by rhythmic beating of appendages.

This typical respiratory mechanism is found in the primitive malacostracan - precaridan and eucaridan. In this process, there is a forward moving stream of water drawn in over the posterior and lateral edges of the thoracic appendages and discharged anteriorly on either side of mouth (Gampbell, 1930). The water flow is kept constant by the rhythmic
movements of epipodite and exopodite. In addition to it, the antenna and antennule generally remain parallel to the current within the exhalent prebranchial chambers.

The inflow of the water becomes restricted to the base of the thoracic appendages having fringed epipodites and exopodites, which has a special advantage in respiration.

**MATERIALS AND METHODS**

Shrimps, *Streptocephalus dichotomus* used in the present study were collected from the fresh-water temporary ponds around Aurangabad. The shrimps were acclimatised to the laboratory conditions before the experiment. Both, male and female, were used for the experimental purpose. The ventilation frequency (the movement of the thoracic appendages) was counted per minute both in changing temperature and salinity of the medium.

The animals were taken in a small petri dish for the experimental purpose in which a thermometer was constantly kept for recording the water temperature. At the time of the experiment all other laboratory and the environmental conditions were kept constant. The experimental dish was kept in a large dish having water to keep the temperature constant at the required level. The required water temperature was obtained by adding the hot water or the ice-blocks to the outer dish, thus the gradual change in water temperature of the experimental dish was obtained up to the required mark.
The different percentage of saline water was prepared with the help of NaCl and the salinity was estimated by titrating the solution with silver nitrate solution (Harvey, 1928).

**OBSERVATIONS AND RESULTS**

**Experiment 1:**

**The effect of temperature on the ventilation frequency**

A shrimp of moderate size about 20 mm. in length was used for the experiment. For the first reading, the normal pond water was used having $28^\circ$C. ± 0.5$^\circ$C. temperature. The shrimps were allowed to acclimatise for ten minutes. The movements of the thoracic appendages per minute were counted as ventilation frequency. Minimum five readings at a particular temperature were recorded and the experiment was repeated with specimens of different sizes.

Different sets of observations at different temperature after gradually lowering the water temperature of the inner dish by adding ice-blocks to the outer dish were recorded. Afterwards the water temperature was gradually increased by adding hot water to the outer dish and different sets of observations were recorded.

The Table 4 gives the ventilation frequency recorded at $18^\circ$C., $23^\circ$C., $28^\circ$C., $33^\circ$C. and $38^\circ$C.
It was observed that there is a remarkable increase in the ventilation frequency with the increase in temperature and decrease in the ventilation frequency with the decrease in the temperature.

**Experiment 2:**

*The effect of salinity at different temperature on the ventilation frequency*

0.1%, 0.2% and 0.3% saline solutions were prepared with the help of standard NaCl. The shrimp was allowed to acclimate with 0.1% saline solution for about fifteen minutes. At least five readings of the ventilation frequency at each of these levels of temperature (22°C., 27°C., 33°C. and 38°C.) were recorded. The mean values of the observations were calculated at corresponding temperature. The experiment was repeated for different percent of salinity. (Table 5)

It was observed that the ventilation frequency increases with salinity only up to 3% of salinity. At higher salinity the animal shows distress and the movements become erratic.

**DISCUSSION**

The standard rate is the minimal rate of metabolism and the active rate is the level of oxygen consumption at maximal activity. The difference between these two rates defines the 'scope for activity' in the organism (Fry, 1947). It is an observed fact that the active rate of metabolism rises
steeply with temperature, since activity itself is markedly temperature-dependent.

The scope for activity did not increase continuously with higher temperatures whereas it was reduced at high temperature. The decline in the scope for activity at the extremes of the temperature range suggests, why the optima for animal activity fell within the tolerance range of the organism. The flattening of the curve relating the rate of metabolism to temperature would indicate an important homeostatic mechanism in a poikilotherm, which would allow the rates of metabolic reactions to proceed at a relatively constant rate despite the large fluctuations in temperature of the habitat (Bullock, 1955; Davies, 1966; Newell, 1966, 1969; Newell and Northcroft, 1967).

In the _Streptocephalus dichotomus_ it was observed that with the increase in temperature, the activity rate i.e. the ventilation frequency increases which directly affects the rate of oxygen consumption i.e. the rate of metabolism.

It clearly indicates that the ventilation frequency or the activity of the thoracic appendages are mostly responsible for the rate of respiration. Thus by implication they are the chief respiratory organs of the organism.
TABLE 4

Ventilation frequency per minute at different temperatures of *Streptocephalus dichotomus*

<table>
<thead>
<tr>
<th>Set No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>18°C.</td>
<td>23°C.</td>
<td>28°C.</td>
<td>33°C.</td>
<td>38°C.</td>
</tr>
<tr>
<td>Consumed O₂ ml./gm./hour/litre</td>
<td>0.14</td>
<td>0.21</td>
<td>0.245</td>
<td>0.35</td>
<td>0.42</td>
</tr>
<tr>
<td>Ventilation frequency per minute</td>
<td>128</td>
<td>150</td>
<td>170</td>
<td>202</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>152</td>
<td>166</td>
<td>200</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>128</td>
<td>152</td>
<td>170</td>
<td>200</td>
<td>216</td>
</tr>
<tr>
<td></td>
<td>132</td>
<td>148</td>
<td>168</td>
<td>198</td>
<td>218</td>
</tr>
<tr>
<td></td>
<td>132</td>
<td>152</td>
<td>166</td>
<td>200</td>
<td>218</td>
</tr>
<tr>
<td>Mean</td>
<td>130.0</td>
<td>150.8</td>
<td>168.0</td>
<td>200.0</td>
<td>217.6</td>
</tr>
<tr>
<td>SD</td>
<td>0.7069</td>
<td>0.6707</td>
<td>0.7069</td>
<td>0.5000</td>
<td>0.4471</td>
</tr>
<tr>
<td>SE</td>
<td>0.2237</td>
<td>0.2000</td>
<td>0.2237</td>
<td>0.1581</td>
<td>0.9997</td>
</tr>
</tbody>
</table>
**TABLE 5**

Ventilation frequency per minute of different salinity of *Streptocephalus dichotomus*

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Control</th>
<th>Salinity (mean values)</th>
<th>0.1%</th>
<th>0.2%</th>
<th>0.3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>28°C</td>
<td>168</td>
<td>193</td>
<td>197</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>33°C</td>
<td>201</td>
<td>204</td>
<td>202</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>38°C</td>
<td>218</td>
<td>214</td>
<td>214</td>
<td>208</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE - 7

Oxygen consumption in relation to temperature

Experimental conditions:

Room temperature ... 30°C.
Water temperature ... 27°C.
Oxygen ml./litre ... 0.32
pH ... ... ... 7.5
O₂ Consumption in relation to temperature

O₂ ml/gm.wt./hour/1.at N.T.P

Temperature °C

0°C 17 20 30 40
FIGURE - 8

Oxygen consumption in relation to salinity

Experimental conditions:

- Room temperature ... 30°C.
- Water temperature ... 27°C.
- Oxygen ml./litre ... 0.32
- pH ... ... ... 7.5
O\textsubscript{2} CONSUMPTION IN RELATION TO SALINITY IN \textit{S. dichotomus}.
FIGURE - 9

The effect of pH on oxygen consumption

Experimental conditions:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room temperature</td>
<td>30°C.</td>
</tr>
<tr>
<td>Water temperature</td>
<td>27°C.</td>
</tr>
<tr>
<td>Oxygen ml./litre</td>
<td>0.32</td>
</tr>
</tbody>
</table>
The effect of oxygen concentration on oxygen consumption.

**Experimental conditions:**

- Room temperature ... 30°C.
- Water temperature ... 27°C.
- pH ... ... ... 7.5

The effect of body size on oxygen consumption

**Experimental conditions:**

- Oxygen ml./litre ... ... 0.32

(Other experimental conditions are as per Figure-10)
FIGURE - 12

The relation between ventilation frequency and oxygen consumption.

0 : Ventilation frequency
● : Oxygen consumed
The relation between ventilation frequency and O₂ consumption

Ventilation frequency / minute

O₂ ml/gm.wt/hour/Lat.N.T.P.

TEMPERATURE °C.
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