T H E S I S

submitted by

P.V. CHERIYAN, M.Sc.,

for

THE Ph.D. DEGREE

of

THE UNIVERSITY OF COCHIN.

1971

This is to certify that this Thesis is an authentic record of the work carried out by Mr. P.V. Cheriyan, M.Sc., under my supervision in the University Department of Marine Biology & Oceanography and that no part thereof has been presented before for any other degree in any university.

Ernakulam,

23-9-1971.

SUPERVISING TEACHER

DR. C. V. KURIAN.

## A C K N O W L E D G E M E N T

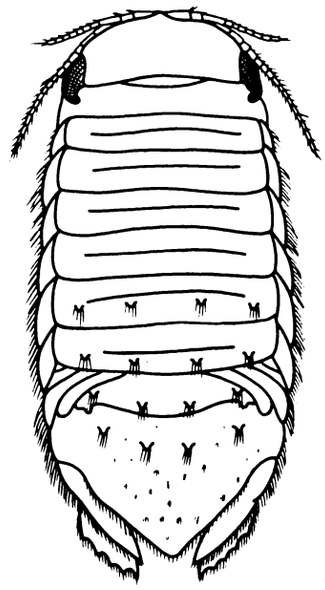
I wish to express my deep sense of gratitude to Dr.C.V. Kurian, Professor of Marine Biology & Oceanography, University of Cochin, under whose guidance this work was carried out and who critically went through the manuscript and made necessary corrections. I am thankful to Mr.S.K. Banerji, Head of Statistics Section, Central Marine Fisheries Research Institute, Cochin, for verifying the statistical part in the thesis. My thanks are also due to many of my colleagues, especially to Dr.V.O. Sebastian, visiting Scientist, for his encouragement and valuable suggestions in the preparation of the thesis, to Mr.T.M. Sankaran, Research Assistant in Statistics, for his help in the statistical analysis of the data and to Mr.C.J. Cherian, who helped me throughout the work.

I am grateful to the President, Forest Research Institute & Colleges, Dehra Dun, for allowing me to carry out this investigation during the period of my employment as Research Officer in the Marine Organisms Scheme at the Cochin Centre. I am also thankful to the authorities of the Cochin University for providing me with necessary facilities to carry out the work.

Sd/-
P.V. CHERIYAN.

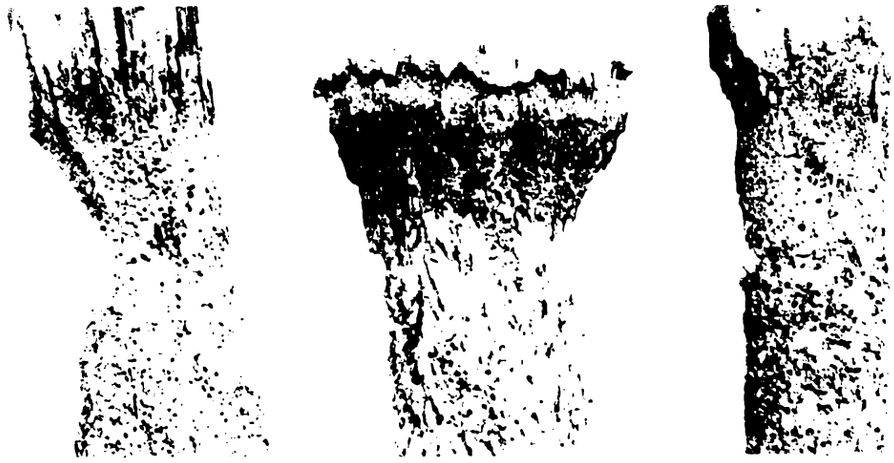
# STUDIES ON *SPHAEROMA TEREBRANS* BATE

# OF THE PORT OF COCHIN



1·0 mm.

SPHAEROMA TEREBRANS BATE — DORSAL VIEW ♀



JETTY PILES DESTROYED MAINLY BY SPHAEROMA

# STUDIES ON *SPHAEROMA TERREBANS* BATE

# OF THE PORT OF COCHIN

## C O N T E N T S



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# CHAPTER I

## INTRODUCTION

Destruction of timber in the sea by the attack of marine borers has been reported from very early times. The important borers in sea responsible for the destruction of wooden structures like wooden ships, piles, dikes, jetties etc. belong to mainly two phyla, the Mollusca and Arthropoda. In the phylum Mollusca the borers are species of Teredo and Bankia (Family Teredinidae) and species of Martesia (Family Pholadidae). In the phylum Arthropoda the borers are species of Sphaeroma (Family Sphaeromidae) and species of Limnoria (Family Limnoriidae). In early days Teredo was believed to be a worm and it was Godfrey Sellius (1733) who first identified it as a bivalve. The first record of Limnoria is by Leach (1813) and it is Bate (1866) who demonstrated the timber destroying habit of Sphaeroma.

Along with the increased use of timber for underwater structures, the problem of marine timber destroying agents also began to reach new proportions. As a result, a scientific approach to the problem of protecting timber, against the attack of marine wood-borers became imperative. In India, the commencement of the 'Marine Organisms Scheme' by the Forest Research Institute, Dehra Dun, in 1954 marked the beginning of a systematic and scientific approach to this problem.

The wood destroying character of Sphaeroma terebrans reported by Bate (1866) was based on observations made on specimens collected by Fritz Muller from Brazil. In the same year he described Sphaeroma vastator from Madras Museum collections which were made by Capt. Mitchell from the backwaters of the West Coast of India. The earliest report on wood destroying isopods in America was made by Richardson (1897). This report dealt with Sphaeroma destructor collected from timber pieces in the fresh water regions of St. John river, Florida. In 1900 Hedley reported a species of Sphaeroma from the Rewa river in Fiji. He has also reported on the occurrence of Sphaeroma quoyana in Sydney harbour, Australia. Richardson (1910) reported Sphaeroma peruvianum from Peru. Teesdale (1914) reported on Sphaeroma destructor and

has stated that it forms one of the important borers in marine wood work. From Sydney harbour, McNeill (1932) has listed Sphaeroma quoyana, Sphaeroma terebrans and Sphaeroma walkeri. The former two species are reported as serious wood-borers compared to the latter which is not a true wood-borer. Calman (1936) has stated that in warmer waters the damage to timber is mainly caused by members of the isopod genus Sphaeroma and according to him the damage to timber is reported from California, Florida, Brazil, the Cape, India, Ceylon, Australia and New Zealand, mostly in brackish or fresh water regions.

In India Sphaeroma vastator was recorded from Madras by Bate (1866) and Sphaeroma triste by Heller (1868) from Nicobar. Stebbing (1904) described Limnoria (L.) pfefferi from Minicoy Islands, and Barnard (1936) described Limnoria (L.) septima from Andamans. Pillai (1961) has published a consolida account of the systematics, habits, and distribution of the sphaeromid and limnorid wood-borers of India. John (1968) has studied the anatomy and development of Sphaeroma terebrans occurring in Cochin harbour.

The distribution of sphaeromids in a variety of environments namely, in sea, estuaries, brackish water and fresh water subjects them to a variety of stresses, and as a consequence populations in different habitats exhibit physiological adaptations and variations of different magnitude. Prosser (1955 & 1958) and Bullock (1955) in their exhaustive reviews have stressed the importance for study of the nature of physiological adaptations and variations in different animal populations.

Studies on animal populations hailing from different hydrographical and geographical habitats would be of interspecific and intraspecific value for a comprehensive knowledge on their physiological adaptations. Because of the occurrence of sphaeromids in a variety of environments, they form an interesting group of animals for detailed physiological study. Since all the physiological processes of animals are related to their respiratory metabolism, a study of the latter in relation to more important ecological factors in their environment namely salinity, temperature and oxygen tension is of considerable interest. A perusal of literature would show that studies on these aspects on sphaeromids are lacking. However, mention may be made

on studies conducted on isopods to which sphaeromids belong. Reinders (1933) carried out studies on Porcellio scaber. Fox, Simmonds and Washbourn (1935) determined metabolic rates of Asellus aquaticus from swiftly flowing, and also still waters. Muller (1943) studied respiratory rate of Armadillidium pallasii. Edwards (1946) studied the influence of temperature upon the oxygen consumption of a number of arthropods including Oniscus asellus. Ellenby (1951) conducted studies on body size in relation to oxygen consumption and pleoped beat in Ligia oceanica. Edney and Spencer (1955) investigated the cutaneous respiration in the above species, and Eltringham (1965a) the respiratory rate of Limnoria in relation to salinity.

From the above account it is obvious that the investigations on the respiratory metabolism of sphaeromids have not been done so far. Hence, Sphaeroma terebrans Bate, an important crustacean wood-boring organism in the Cochin harbour area situated along the South West Coast of India (Ref: figs. 1 & 2), was selected for the study.

For the better understanding of the animal selected for the study, its habitat, breeding and seasonal variations in attack on timber and salinity tolerance were also studied and are reported in the present work.

The collection of data on the hydrographical conditions at the Oceanographic Laboratory jetty (site of field tests) was started in 1958 and is being continued on a long term basis. Field studies on the habitat, breeding and seasonal variations in the attack on timber have been undertaken from 1965 to 1968. Laboratory experiments on the salinity tolerance and respiration were carried out during 1968 and 1969.

(A separate introduction is given to the part dealing with the various aspects of respiration).

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FIG.I

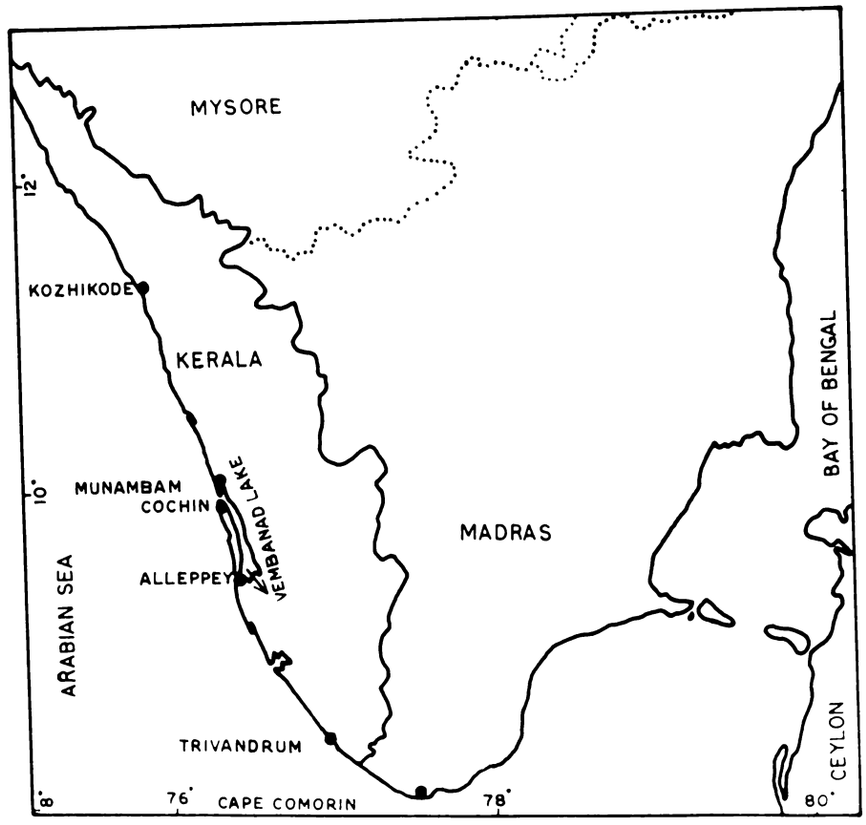
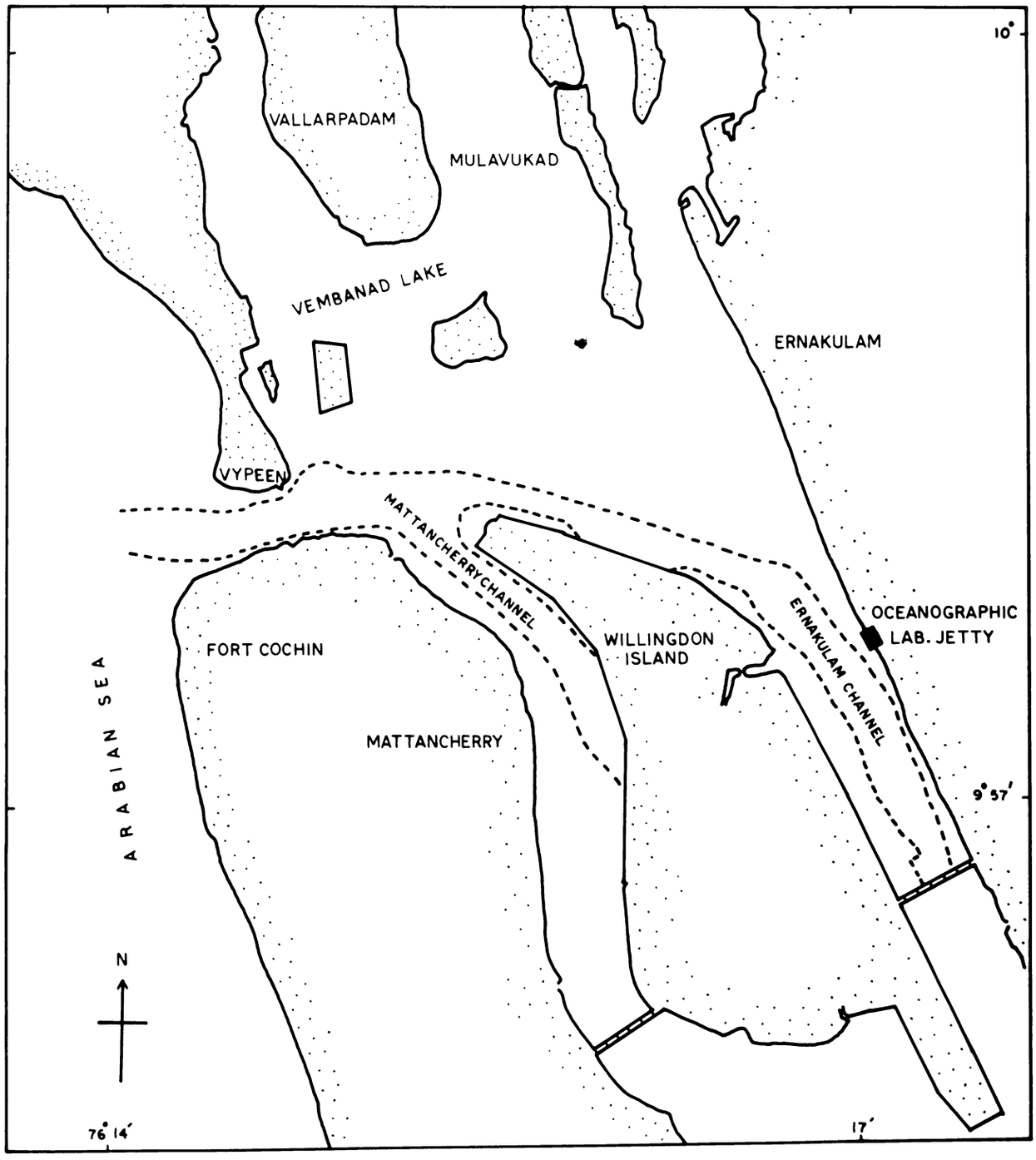

MYSORE
12°
KOZHIKODE
KERALA
10°
MUNAMBAM
COCHIN
VEMBANAD LAKE
ALLEPPEY
MADRAS
BAY OF BENGAL
ARABIAN SEA
TRIVANDRUM
8°
76°
CAPE COMORIN
78°
80°
CEYLON

FIG. 2

MAP OF COCHIN PORT SHOWING THE
OCEANOGRAPHIC LABORATORY JETTY
(TEST SITE)

FIG.2


10°
VALLARPADAM
MULAVUKAD
VEMBANAD LAKE
ERNAKULAM
VYPEEN
MATTANCHERRY CHANNEL
ERNAKULAM CHANNEL
OCEANOGRAPHIC
LAB. JETTY
WILLINGDON
ISLAND
FORT COCHIN
MATTANCHERRY
ARABIAN SEA
N
9° 57'
76° 14'
17'

# CHAPTER II

## HABITAT

Nearly twenty species of sphaeromids, popularly known as "pill-bugs", have been recorded from different parts of the world. They are reported as occurring from marine to fresh water conditions. According to Richardson (1904) nine species are recorded from "brackish and subterranean waters and even from artesian wells, warm springs and rivers". While most of the species are free living, a few make burrows in timber or stone. The free living forms are usually found in the crevices of stone embankments, timber structures etc. submerged in water. They have also been found clinging to floating plants or other structures. Usually they prefer to occupy discarded burrows of other animals or empty shells of barnacles. The burrowing forms are also occasionally found to swim short distances or creep about on the surface of the substratum. Laboratory observations show that they always swim with their ventral side up.

In 1919 Barrows reported that atleast five species of sphaeromids burrow into timber or stone. Later, the number of such species increased. Sphaeroma terebrans, S. quoyana, S. annandalei, S. annandalei var. travancorensis, S. peruvianum, S. sieboldii and S. retrolaevis have been proved to be true wood-borers.

To the wood-boring sphaeromids, whether they subsist on timber or only make burrows in it for shelter, submerged timber in one form or other is found to be essential for their existence. The easy availability of timber in the harbours, estuaries, brackish water and fresh water regions might have worked as a tempting force on these animals to colonise in these places. The capacity to tolerate wide fluctuations in salinity is a prerequisite for such colonisation and this might have been slowly acquired.

Some of the sphaeromids are marine, while others are found in estuaries. Many of them have acquired a high degree of tolerance to salinity variations. Sphaeroma walkeri is not a true wood-borer. It is predominantly marine and is usually found along the sea coast, but sometimes individuals are observed

in estuaries. On the other hand S. annandalei is found in the sea, estuary and backwaters. S. terebrans has not so far been reported from the open sea, but is abundantly found distributed in estuaries and backwaters of Kerala. It has also been reported from the Mediterranean, North Africa, South Africa, Congo, Mozambique, Zanzibar, Ceylon, Queensland, Florida and Brazil.

Timber which is heavily attacked by Sphaeroma presents the appearance of a honey comb, each burrow being separated by only a thin film of wood. The burrows are generally at right angles to the surface of wood, perfectly cylindrical, up to 20 mm in depth and up to 8 mm across, depending on the size of the individuals. Though Sphaeroma is capable of burrowing even smooth surfaces, it is found to prefer easily vulnerable points like cracks, nail holes and scratches on the surface of timber.

Heavy attack of sphaeromids is usually found limited to intertidal regions of wooden structures (Pillai, 1961; Cheriyan, 1964a; Nair, 1966 and John, 1968). McNeill (1932) has reported that tests carried out on timber structures in sea did not show any attack below low-tide mark. In the Cochin harbour region Sphaeroma attack has been occasionally observed up to 3 feet below low-tide level. Heavily attacked wooden piles removed from the harbour region showed as many as 24 burrows in a 2.5 cm x 2.5 cm square area. The maximum number was usually found in the intertidal region and lesser number at higher and lower tide levels.

Laboratory tests showed that if Sphaeroma is provided with soft and hard substrata simultaneously, they always showed a preference to soft substrata and made burrows in them. Similar tests also showed that on pieces of timber in which both sap wood and hard wood are present, the sap wood is first attacked generally from the cut ends.

During laboratory observations it was found that once an animal gets into a burrow in the timber piece provided in the aquaria, it seldom moved out of it. Only very rarely individuals were found creeping about. It was further observed that if a timber piece with empty burrows of Sphaeroma is provided to them, they quickly moved about and occupied the burrows

according to their sizes and new burrows were made only if they failed to get suitable burrows.

In the laboratory it was observed that if water in the aquaria gets polluted Sphaeroma came out of their burrows, moved about and clung to the inner surface of the aquarium tanks. Many creeped out of water and remained partly rolled up. In this state they could survive 20 to 24 hours. Exposure tests in the laboratory also showed that they are capable of remaining out of water 20 to 24 hours under room temperature 28°C and relative humidity 70 to 80 %.

In India four species and a variety of sphaeromids have been recorded. They are Sphaeroma triste, S. annandalei, S. annandalei var. travancoremsis, S. walkeri and S. terebrans. Of these, except S. triste which occurs in Madras and Nicobar Islands, all others are found to occur in Kerala. S. walkeri is met a herer. In the Cochin harbour region S. annandalei is not found in large numbers compared to S. terebrans which occurs abundantly causing enormous damage to underwater timber structures because of their boring habit.

As already mentioned Sphaeroma terebrans is the most important wood-boring isopod that occurs abundantly in the Cochin harbour area situated along the South West Coast of India. On the West Coast of Kerala there are a number of backwaters connected by canals extending from Cranganore to Trivandrum. The biggest and most extensive one is the Vembanad lake, which stretches from Alleppey to Munambam ( Ref: Fig. 1 ). Its geographical position is between latitudes 9°28' and 10°10' North and longitudes 76°13' and 76°31' East. Its length is about 115 Km. and breadth up to 15 Km. The Cochin harbour is situated near the northern end of this lake. A deep approach channel nearly 15 Km. long is being maintained for the incoming and outgoing ships. In the Cochin harbour region there is an island, artificially made, known as the Willingdon Island. Many rivers discharge themselves into this lake, the principal ones being the Achankoil, the Pambai, the Manimala, the Meenachil, the Muvattupuzha and the Periyar rivers. All these rivers originate from the Western Ghats. They carry enormous quantities of rain water and silt into the lake during the rainy

seasons and these considerably affect the composition of water in the lake. Consequently the hydrographical conditions in the Cochin harbour region are largely influenced by the heavy rainfall and the flow of sea water in and out of the lake through the harbour opening. The monthly fluctuations in temperature, salinity, oxygen, phosphate, silicate, nitrite, pH as well as the rainfall are given in table 1 and the more important ecological factors are also presented in fig. 3.

From an analysis of the data presented in table 1 and fig. 3, it is possible to make out three hydrographical seasons namely monsoon season (June to August), post-monsoon season (September to December) and summer season (January to May) prevailing in the region. During the monsoon season the sea water from the harbour region is flushed out into the sea by the strong seaward flow of fresh water from the neighbouring region. During the post-monsoon season, the flow of fresh water into the sea is comparatively less and as a result the harbour region slowly comes under the influence of the neighbouring sea. This influence of sea gradually increases and during the summer season almost marine conditions prevail in the harbour.

From the foregoing account it will be seen that the wood-boring isopod, Sphaeroma terebrans found abundantly in the Cochin harbour region is subjected to extreme variations in hydrographical conditions, especially salinity during the course of a year.

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## TABLE I

**Showing variations in the hydrographical conditions during the different months at the test site during 1968.**

(Oceanogr. Lab. Jetty)*

| | Temperature °C | Salinity ‰ | Oxygen ml/L | Phosphate µg at./L | Nitrite µg at./L | Silicate µg at./L | pH | Rainfall cm |
|---|---|---|---|---|---|---|---|---|
| January | 28.8 | 31.20 | 4.72 | 0.55 | 0.30 | 20.0 | 8.2 | Trace |
| February | 30.1 | 33.12 | 4.17 | 0.85 | 0.60 | 8.0 | 8.2 | 2.17 |
| March | 31.5 | 33.68 | 4.17 | 0.90 | 0.50 | 8.0 | 8.4 | 8.74 |
| April | 31.8 | 33.84 | 3.39 | 1.00 | 0.65 | 13.0 | 8.4 | 12.83 |
| May | 31.1 | 28.56 | 5.15 | 1.10 | 0.70 | 15.0 | 8.4 | 15.34 |
| June | 27.9 | 1.36 | 4.17 | 1.33 | 0.75 | 25.0 | 8.2 | 68.81 |
| July | 28.0 | 0.28 | 6.20 | 1.00 | 0.70 | 25.0 | 7.2 | 144.98 |
| August | 28.4 | 2.25 | 5.75 | 0.75 | 0.45 | 22.5 | 7.2 | 26.97 |
| September | 29.4 | 4.72 | 4.33 | 0.56 | 0.22 | 20.0 | 7.4 | 20.23 |
| October | 29.0 | 16.56 | 5.75 | 0.80 | 0.55 | 18.0 | 8.0 | 15.34 |
| November | 30.3 | 20.96 | 5.60 | 1.10 | 0.70 | 15.0 | 8.0 | 12.07 |
| December | 28.3 | 29.88 | 5.01 | 0.95 | 0.65 | 15.2 | 8.0 | 5.87 |

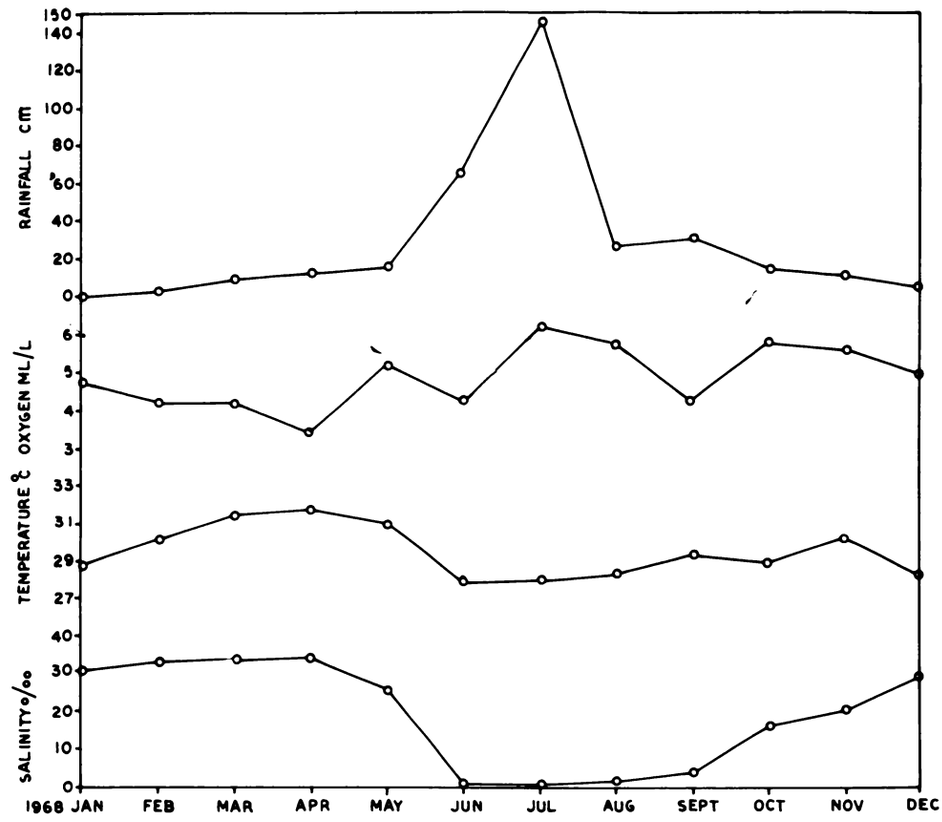
* Though data for the last 10 years are available, only data of one year (1968) is given here so as to show the pattern of variation.

** Rainfall data was collected from I.N.S. Garuda, Willingdon Island.

FIG. 3

Showing the monthly fluctuations in the important hydrographical conditions in the habitat of Sphaeroma terebrans during 1968 (Oceanographic Laboratory Jetty).

FIG.3


RAINFALL cm
130
140
120
100
80
60
40
20
0
OXYGEN ML/L
6
5
4
3
TEMPERATURE °C
33
31
29
27
SALINITY °/oo
40
30
20
10
0
1968 JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC

# CHAPTER III

## BREEDING OF SPHAEROMA TEREBRANS BATE AND ITS ATTACK ON TIMBER

### BREEDING

Pillai (1961) has stated that breeding of sphaeromids in the backwaters of Kerala is continuous. Cheriyan (1964b), Nair (1965) and John (1968) have reported on the variations in the intensity of attack during the different seasons by sphaeromids in the Cochin harbour region. Even though the above publications are already available on Sphaeroma of the Cochin harbour region, it was felt necessary to carry out more detailed studies on the breeding and attack of the animals in the field along with the laboratory studies on the salinity tolerance and respiration of the species, for a better interpretation and fuller understanding of the latter aspects.

The study of the seasonal variations in the intensity of breeding in Sphaeroma terebrans was made by collecting timber pieces infested by Sphaeroma from the harbour region during the years 1965 to 1968. From such pieces an area of 15 cm x 15 cm was marked out and examined for the young and adult stages of the animal. A dozen of such samples were examined every month. All the individuals present in the timber were carefully extracted from their burrows and they were sorted out into groups (1) immature animals of length 2 to 4 mm, (2) mature animals of length above 4 mm carrying developing eggs or embryos and (3) adults without eggs or embryos in the breed pouch. The basis for the above grouping was that when the young ones emerge out of the breed pouch they are about 2 mm long and until they reach about 4 mm size they are found along with the mother or in the neighbourhood of the burrow occupied by the mother. They do not possess eggs in the breed pouch and are considered immature. Only those above 4 mm size are found to possess eggs or developing embryonic stages in their breed pouch. But the number of such individuals is not considerable. From 7 mm size onwards berried females are very common. Among the adult specimens collected from the natural habitat males formed only about 4 %.

The percentage of the animals in the three groups mentioned above was calculated in relation to the total collection and is presented in table 2 and fig. 4.

(1) Immature ones (2 to 4 mm size):- The number of animals of this group is almost the same during January to March (apprex. 35 %). Afterwards there is a sharp decline during April and May (12 %). Again the number increases gradually in the following months till it reaches the maximum in September (60.8 %). Then there is a sudden fall to 43.5 % in October and reaches 40.70 % in December.

(2) Mature females with eggs or embryos in the breed pouch (above 4 mm):- In January animals of this group reach 31.41 % and then there is a decrease up to March (17.95 %), and this condition prevails up to May. During June the number increases (35.86 %) and the intensity remains almost the same in July, and rises up to the maximum in August (44.82 %). There is a lowering again in September to 34.39 % and then it shows an increase with another peak in November (39.86 %). Taking the total percentage of the free swimming immature forms and adults with eggs or embryos it is found that the lowest number is in May and then it gradually rises to reach the peak during August - September. There is a gradual decline in the following months up to December.

(3) Mature females without eggs or embryos in their breed pouch (above 4 mm):- In January animals of this group form 33.49 % and during the following months there is a steady increase up to May reaching the maximum of 70.96 %. During June there is a steep fall to 36.74 % and then the number further decreases to reach the minimum in September (4.81 %). From October onwards there is a rise in the number reaching 24.64 % in November and afterwards a slight decrease in December (23.61 %) is observed.

In the region under study, June, July, August and September are the rainy months when the salinity in the harbour area is comparatively very low. It may be seen from table 2 (page 11) that during the above period there is a progressive increase in the total percentage of the young and berried females. During the later months when the salinity increases, the percentage of the above group decreases.

## TABLE 2

**Showing the variations in the percentage of different stages of Sphaeroma terebrans during the different months during 1968.***

| Months | % of different stages. | | | | Salinity ‰ | Temperature °C. |
|---|---|---|---|---|---|---|
| | Free swimming immature forms (1) | Adults with developing embryos (2) | Total of (1)+(2) | Adults without developing embryos. | | |
| January | 35.10 | 31.41 | 66.51 | 33.49 | 31.20 | 28.8 |
| February | 36.60 | 25.94 | 62.54 | 37.46 | 33.12 | 30.1 |
| March | 35.20 | 17.95 | 53.15 | 46.85 | 33.68 | 31.5 |
| April | 19.80 | 19.20 | 39.00 | 61.00 | 33.84 | 31.8 |
| May | 12.40 | 16.64 | 29.04 | 70.96 | 26.56 | 31.1 |
| June | 27.40 | 35.86 | 63.26 | 36.74 | 1.38 | 27.9 |
| July | 35.60 | 36.32 | 71.92 | 28.08 | 0.28 | 28.0 |
| August | 48.30 | 44.82 | 93.12 | 6.88 | 2.25 | 28.4 |
| September | 60.80 | 34.39 | 95.19 | 4.81 | 4.72 | 29.4 |
| October | 43.50 | 36.87 | 80.37 | 19.63 | 16.56 | 29.0 |
| November | 35.50 | 39.86 | 75.36 | 24.64 | 20.96 | 30.3 |
| December | 40.70 | 35.69 | 76.39 | 23.61 | 29.88 | 28.3 |

* Out of the data collected during four years (1965 to 1968) only that of 1968 is presented as a typical case.

FIG. 4

Showing the monthly variations in the percentage of different stages of Sphaeroma terebrans, salinity and temperature during 1968 (Oceanographic Laboratory Jetty).

FIG. 5

Showing the monthly variations in temperature, salinity and attack by Sphaeroma terebrans during 1968 (Oceanographic Laboratory Jetty).

FIG.4

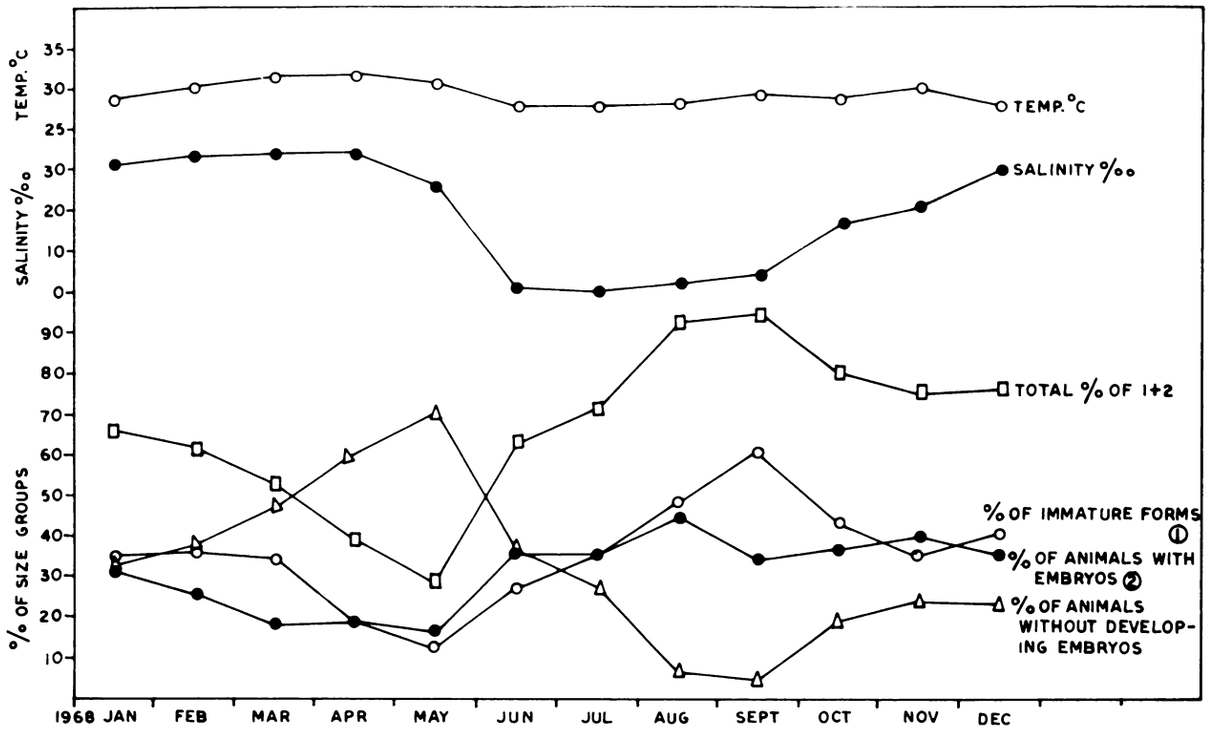
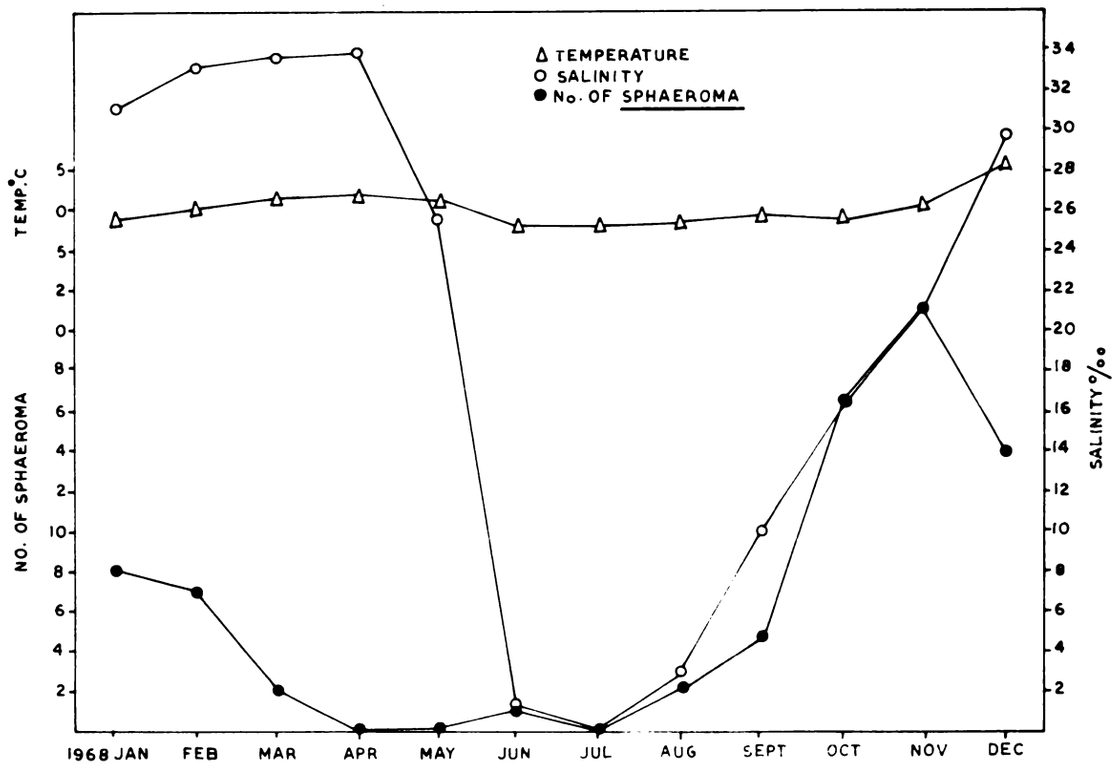

TEMP.°C
SALINITY ‰
% OF SIZE GROUPS
TEMP.°C
SALINITY ‰
TOTAL % OF 1+2
% OF IMMATURE FORMS ①
% OF ANIMALS WITH EMBRYOS ②
% OF ANIMALS WITHOUT DEVELOPING EMBRYOS
1968 JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC

FIG.5


Δ TEMPERATURE
O SALINITY
● No. OF SPHAEROMA
TEMP.°C
NO. OF SPHAEROMA
SALINITY ‰
1968 JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC

The temperature variation in the harbour waters in the different months is not considerable. The lowest temperature is in June (27.9°C) and the highest in April (31.8°C). Hence temperature does not appear to play an important role in the breeding propensities of Sphaeroma terebrans in this locality.

John (1968) has stated that "field experiments confirmed the results of laboratory tests which showed that for Sphaeroma terebrans the optimum conditions for growth and reproduction is a salinity range of 4 to 28 ‰". In the present studies the maximum percentage of the young and berried females are observed during August and September (93.12 % and 95.19 %) when the salinity is 2.25 ‰ and 4.72 ‰, respectively, and as the salinity increases the percentage of the above group shows a decrease.

ATTACK ON TIMBER

For studying the seasonal variations in attack on timber by Sphaeroma terebrans, test panels of mango wood (Mangifera indica) of size 15 cm x 5 cm x 2.5 cm were fixed to iron frames and suspended horizontally at the low tide level in the test site. As the sphaeromids prefer soft timbers for boring, mango wood which is easily available in the locality was selected for making the test panels. Six test panels were exposed at a time in each month. At the end of every month the exposed test panels were removed to the laboratory and fresh sets were immersed. The number of animals in all the removed test panels was counted and from the total, the average number for one test panel was calculated. This procedure was followed every month for a period of four years from 1965 to 1968.

A scrutiny of the data presented in table 3 and fig. 5 will show that the attack of Sphaeroma is moderate in January with an average of 8 animals per panel. In February the attack was less with 7 animals per panel and in March it was much lower with only 2 animals per panel. During April to July the attack was negligible. In August the intensity of attack showed an upward trend with 3 animals per panel and in September a sudden increase was found with 10 animals per panel. The same trend was kept up in October

## TABLE 3

**Showing the monthly variations in temperature, salinity and attack by *Sphaeroma terebrans* during 1968.***

| Months | Temperature °C | Salinity ‰ | No. of *Sphaeroma* |
|---|---|---|---|
| January | 28.8 | 31.20 | 8 |
| February | 30.5 | 33.12 | 7 |
| March | 31.8 | 33.68 | 2 |
| April | 31.1 | 33.84 | - |
| May | 27.9 | 26.56 | - |
| June | 28.0 | 1.36 | 1 |
| July | 28.4 | 0.28 | - |
| August | 29.4 | 2.25 | 3 |
| September | 29.0 | 4.72 | 10 |
| October | 30.3 | 16.56 | 16 |
| November | 28.3 | 20.96 | 21 |
| December | 28.8 | 29.88 | 14 |

* Out of the data collected for four years (1965 to 1968) only that of 1968 is presented as a typical case.

and November and the maximum number of 21 per panel was reached in November. In December the intensity of attack showed a slight decline with 14 animals per panel.

From what is described above it will be seen that during April and May breeding is minimum as observed from infested timber samples collected from the harbour area. In this period there is no attack on monthly test panels also. This may be due to the high salinity. But during June when the salinity in the harbour area becomes low there is a sudden increase in breeding which continues till December, but an increase in the attack on test panels is not observed during June to August. This may be due to high turbidity and fast currents in the harbour region owing to floods in the above period which disable the young sphaeromids to settle on the test panels.

It is reported by Johnson (1935) and Some (1940) that fresh attack of Limneria is confined to certain seasons. According to Johnson, the period of migration is preceded by the period of intensive reproduction and the consequent overcrowding of population in a particular region. Some (1940) observed a correlation between migration, breeding and temperature in the environment. The view of Some has been held by Coker (1923) and Monnies (1957). Eltringham and Hockley (1961) and Eltringham (1965b) have reported that in Southampton waters the migration of Limneria is governed by the temperature of water and they did not see overcrowding as a cause of migration.

In the Cochin harbour area, temperature is not highly variable so as to induce any sort of migration of sphaeromids. Generally intense breeding and the consequent overcrowding can be considered as factors responsible for migration and settlement in new areas. In the Cochin harbour region the above conditions in the rainy season do not seem to help the animals in finding new areas of settlement due to high turbidity and fast currents. However, when the turbidity is less and currents slow, the intensity of attack increases as seen in September, October and November.

The method of burrowing and migration were carefully studied by

exposing long term test panels of soft timbers like Mangifera indica, Bombax malabaricum and Erythrina indica. During extraction of the animals it was observed that very small specimens liberated from the breed pouch of the mother were found to make pits of their body-size from the burrow occupied by the mother. But as they grew up in size they were found to leave their initial burrows and start making independent burrows in the neighbourhood of the previous burrow, thereby showing a gregarious habit (see figs. 6 & 7). During their further growth when they encounter scarcity of space they migrate to other localities, and the size of such migrating individuals was found to be above 4 mm. The Sphaeroma after having gained a firm foothold in the burrow it makes it bigger and bigger as its size increases and it firmly clings to it. Pulling out of the animal without causing injury has been found difficult and so for getting live animals, the timber had to be carefully split into pieces.

FIG. 6

Diagrammatic representation of the burrows of young *Sphaeroma terebrans* made from the edges of the burrow occupied by the mother.

FIG. 7

Diagrammatic representation of the burrows of young *Sphaeroma terebrans* around the burrows of their mothers showing a gregarious habit.

FIG.6

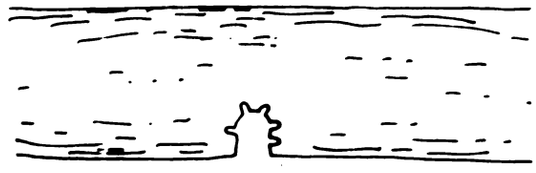
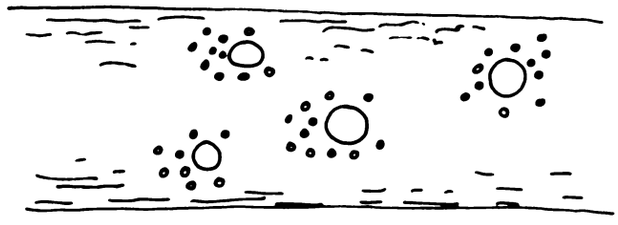


FIG.7



# CHAPTER IV

## LABORATORY STUDIES ON THE SALINITY TOLERANCE OF SPHAEROMA TEREBRANS BATE

Even though Sphaeroma terebrans is reported to be occurring abundantly in highly varying salinity conditions (Pillai, 1961; Cheriyan, 1964b and John, 1968), information regarding the exact extent of their salinity tolerance and their reactions against gradual and abrupt changes in the salinity of water are not known. Since the animals usually live in burrows excavated in the intertidal region of underwater wooden structures (Cheriyan, John and Pillai loc. cit.) the burrows with the animals get exposed during low-tide. This results in the evaporation of water in the burrows, and as a result the animals are subjected to higher salinity conditions and even desiccation. During monsoon season due to heavy rains the salinity of water gets very much lowered thereby subjecting the animals to very low salinity conditions. In spite of these highly fluctuating salinity conditions, they are found to lead an apparently unaffected life and cause extensive destruction to underwater wooden structures, especially in the intertidal portions of jetty piles, fender piles etc. The present experiments were carried out with a view to finding out the behaviour and tolerance capacity of the species in different salinity media and also the lethal level of the medium for the species. Two acclimation salinity levels were taken for the tests, one higher and the other lower. As the exposed areas are subjected to evaporation and consequent increase in salinity, the higher level was taken as 30 ‰ salinity. The lower level was taken as 5 ‰ salinity, which the water gets during rainy seasons.

### Experiments and results

Specimens of Sphaeroma terebrans for the experiments were collected along with attached timber pieces from the Cochin harbour region when the salinity was about 30 ‰, and the timber with animals in the burrows were kept in aquaria containing water of 30 ‰ salinity for about a month to get the animals acclimated to laboratory conditions. In the same way animals were also collected from the harbour region when the salinity was

about 5 ‰ and were kept in aquaria containing water of 5 ‰ salinity for acclimation. Higher salinity media above 30 ‰ for the experiments were made by evaporating filtered sea water to the required level and low salinity media by dilution with distilled water.

Three series of experiments were conducted by transferring animals acclimated in a particular salinity medium to lower and higher media. These experiments were conducted in the laboratory in glass beakers of 250 cc capacity containing 150 cc water of the particular medium and five animals were kept at a time. The temperature of the water of different salinity was maintained at 28.5°C ± 1° in all the experiments. Each series of experiment was repeated a dozen times.

In deciding the tolerance of the animals in a particular medium the rate of mortality was taken into consideration. The mortality of animals was recorded at intervals of 24 hours, and in cases in which the duration of life was less than 24 hours, mortality was recorded as and when it occurred. From the data collected, the number of days taken to reach 50 ‰ mortality in each medium was noted for comparison. The experiments were not continued beyond the 50 ‰ mortality stage. While transferring as well as during the exposure of the experimental period there was slight evaporation of the medium, and lowering of the level of water. This was made up by adding distilled water up to the original level.

Experiment 1. Transferring of animals acclimated in 30 ‰ salinity directly to lower and higher salinity media.

Animals of 8 to 10 mm size (excluding those with eggs or embryos) acclimated in 30 ‰ salinity medium were extracted from the infested timber and transferred directly to different media of lower and higher salinities ranging from distilled water, 0.5 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰, 50 ‰, 60 ‰, 70 ‰ and 80 ‰. The observations showed that the time taken for 50 ‰ mortality varied in the different media as shown below:

| Salinity media | Time taken for 50 % mortality * |
|---|---|
| Distilled water | 0.83 days |
| 0.5 ‰ | 15.00 " |
| 1.0 ‰ | 21.50 " |
| 5.0 ‰ | 31.00 " |
| 10.0 ‰ | 38.00 " |
| 20.0 ‰ | 45.00 " |
| 30.0 ‰ | 45.50 " |
| 40.0 ‰ | 33.00 " |
| 50.0 ‰ | 10.00 " |
| 60.0 ‰ | 1.70 " |
| 70.0 ‰ | 0.67 " |
| 80.0 ‰ | 0.14 " |

* Average of the 12 experiments.

In the acclimation medium of 30 ‰ salinity, the time taken for 50 % mortality is the maximum (45.5 days). As salinity increases or decreases there is shortening of the time to reach the same level of mortality. In lower salinities the decrease of time to reach 50 % mortality is almost gradual up to 0.5 ‰ salinity. After this there is a sudden fall in the duration from 15 days in 0.5 ‰ salinity to 0.83 days in distilled water. When the salinity of media increases, the fall in the time of mortality is more abrupt having only 10 days in 50 ‰ salinity, 1.7 days in 60 ‰ salinity and still lesser in higher media. This shows that the animals are able to adapt better in lower salinity media than in higher and that the salinity below 0.5 ‰ and above 50 ‰ are lethal to the animal.

Experiment 2. Gradual transferring of animals acclimated in 30 ‰ salinity to lower and higher salinity media.

Animals of 8 to 10 mm size (excluding those with eggs or embryos)

acclimated in 30 ‰ salinity were transferred gradually to lower and higher media. Transferring to lower media was as follows: Thirty animals were kept in 30 ‰ salinity for 24 hours. From this 25 were taken and put in a medium of 20 ‰ salinity leaving 5 animals in the 30 ‰ medium. Again, after 24 hours, 20 were removed to a medium of 10 ‰ salinity leaving 5 in 20 ‰ salinity medium. In this way after every 24 hours animals were transferred to lower media of salinities 5 ‰, 1 ‰, 0.5 ‰ and distilled water leaving 5 animals in each medium from which they were transferred. After the final transfer every medium contained 5 animals. In the same way animals from 30 ‰ salinity medium were also transferred to higher salinities of 40 ‰, 50 ‰, 60 ‰, 70 ‰ and 80 ‰, after every 24 hours. The time taken for 50 % mortality is given below:

| Salinity media | Time taken for 50 % mortality * | Difference in time from the experiment 1 |
|---|---|---|
| Distilled water | 1.00 days | +0.17 days |
| 0.5 ‰ | 22.00 " | +7.00 " |
| 1.0 ‰ | 26.00 " | +4.50 " |
| 5.0 ‰ | 37.00 " | +6.00 " |
| 10.0 ‰ | 41.00 " | +3.00 " |
| 20.0 ‰ | 45.00 " | nil |
| 30.0 ‰ | 45.50 " | nil |
| 40.0 ‰ | 33.00 " | nil |
| 50.0 ‰ | 14.00 " | +4.00 days |
| 60.0 ‰ | 3.00 " | +1.30 " |
| 70.0 ‰ | 1.70 " | +1.03 " |
| 80.0 ‰ | 1.04 " | +0.90 " |

* Average of the 12 experiments.

In 30 ‰ salinity medium the time taken for 50 % mortality is the same as in the previous experiment. When the salinity is lowered, the trend is for a gradual fall in the time taken to reach 50 % mortality and when the salinity is increased there is an abrupt fall in the time

taken for reaching the same level of mortality. It is also found that salinities lower than 0.5 ‰ and higher than 50 ‰ are lethal to the species. The present experiment shows that gradual transferring of the animals from one medium to another increases the duration of time to reach 50 % mortality.

Experiment 3. Gradual transferring of animals acclimated in 5 ‰ salinity to lower and higher media.

Animals of 8 to 10 mm size (excluding those with eggs or embryos) acclimated in 5 ‰ salinity were transferred gradually to lower and higher media ranging from distilled water, 0.5 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰, 50 ‰, 60 ‰, 70 ‰ and 80 ‰. Here also the method of transfer was the same as in the previous experiment. The time taken to reach 50 % mortality in each medium is given below:

| Salinity media | Time taken for 50 % mortality * | Difference in time from the experiment 1 | Difference in time from the experiment 2 |
|---|---|---|---|
| Distilled water | 1.7 days | + 0.87 days | + 0.70 days |
| 0.5 ‰ | 26.0 " | +11.00 " | + 4.00 " |
| 1.0 ‰ | 30.0 " | + 8.50 " | + 4.00 " |
| 5.0 ‰ | 44.0 " | +13.00 " | + 7.00 " |
| 10.0 ‰ | 38.0 " | nil | - 3.00 " |
| 20.0 ‰ | 33.0 " | -12.00 " | -12.00 " |
| 30.0 ‰ | 28.0 " | -17.50 " | -17.50 " |
| 40.0 ‰ | 12.0 " | -21.00 " | -21.00 " |
| 50.0 ‰ | 5.4 " | - 4.60 " | - 8.60 " |
| 60.0 ‰ | 0.96 " | - 0.74 " | - 2.04 " |
| 70.0 ‰ | 0.46 " | - 0.21 " | - 1.24 " |
| 80.0 ‰ | —— | —— | —— |

* Average of the 12 experiments.

The time taken to reach 50 % mortality is maximum in the acclimation medium of 5 ‰ salinity. In lower media the time is less, but comparatively it is more than that found in both the previous experiments. In media higher than 5 ‰ salinity, the time is far below that of the previous experiments. In 40 ‰ salinity medium the time for 50 % mortality is only 12 days. In 80 ‰ salinity none survived. It appears that the animals can better tolerate lower salinities (except distilled water) than higher and the media higher than 40 ‰ are lethal.

The results of the above three series of experiments are illustrated in fig. 8.

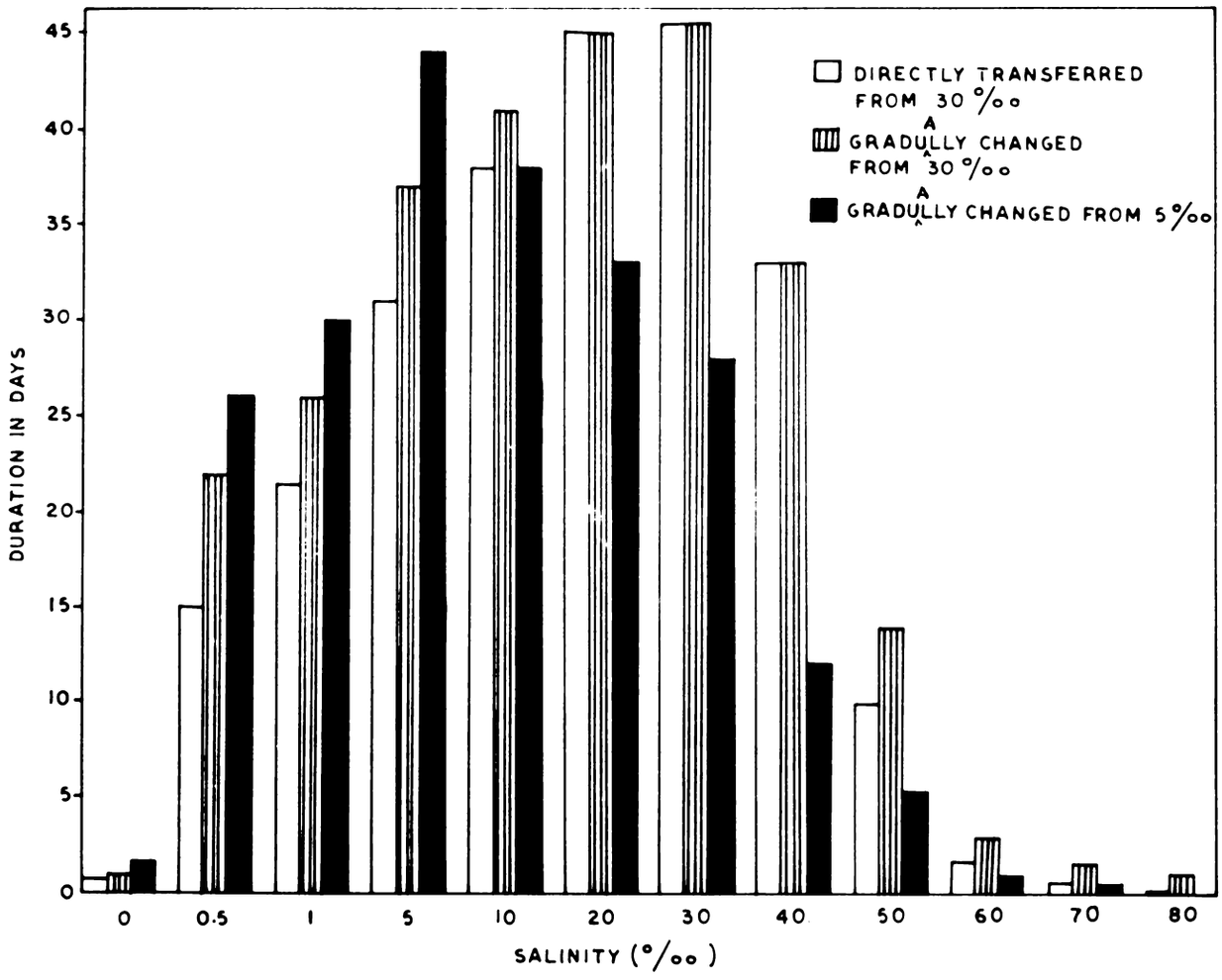
## DISCUSSION

Transferring of isopods from one salinity to another to study the level of tolerance has been done by a few authors. Menzies (1954) made two sub-species of Gnorimosphaeroma oregonensis, one bay form G.o.oregonensis living in intertidal bay of salinity of 25 % sea water (8.61 ‰) and G.o.lutea, a pond form living in a medium of 1.6 % sea water (0.55 ‰), and introduced them in tap water. G.o.oregonensis lived for a day and G.o.lutea for 3 days in tap water. But G.o.lutea was able to survive in sea water. This was conducted to prove the validity of the two sub-species. However, Riegel (1959b) has not accepted the validity of maintaining two sub-species, oregonensis and lutea separately and conducted experiments on tolerance of G.oregonensis to changing media of salinity (Riegel, 1959a). He selected the species from three different types of localities, i.e. fresh water, estuary and bay, and placed them separately in 125 % sea water (43.05 ‰), 100 % sea water (34.44 ‰), 75 % sea water (25.83 ‰), 50 % sea water (17.22 ‰), 25 % sea water (8.61 ‰) and fresh water (0.086 ‰). His observations were for 21 days, and he found that fresh water and estuarine forms survived in all the media of salinities whereas the bay form survived in all salinities except fresh water. He also tested another species collected from the bay, Sphaeroma pentadon in all the salinity media mentioned above, and observations made after 21 days showed that it could survive well in all salinities except

FIG. 8

Illustration of the comparative duration of time taken to reach 50 % mortality in the three series of experiments in the different salinity media.

FIG.8


DIRECTLY TRANSFERRED FROM 30 ‰
GRADUALLY CHANGED FROM 30 ‰
GRADUALLY CHANGED FROM 5 ‰
DURATION IN DAYS
0
5
10
15
20
25
30
35
40
45
0
0.5
1
5
10
20
30
40
50
60
70
80
SALINITY (‰)

in fresh water where it survived only for 11 days.

Hill & Kofoid (1927) have reported that the marine isopod Limnoria could tolerate salinity as low as 6.5 ‰. But according to Menzies (1957) Limnoria cannot tolerate salinities below 10 ‰ for a very long time.

Lockwood and Croghan (1957) experimented with the isopod Mesidotea entomon living in brackish as well as fresh water, and found that the fresh water form could be acclimated to 10 ‰ sea water, whereas the brackish water form could not be acclimated to fresh water.

In the present experiment it is seen that, in the acclimation medium the animals are able to live longer. This is seen in the time taken for 50 ‰ mortality in the case of Sphaeroma terebrans acclimated to 30 ‰ and 5 ‰ salinities, which is almost the same, i.e. 45.5 and 44 days, respectively. In both cases it is seen that as media changed, the life expectancy get shortened. This shortening is more in those directly transferred than to those gradually transferred, and that the decrease in the time taken is gradual in lower salinities and abrupt in higher salinities. It is also found that even though animals acclimated in 5 ‰ salinity take 44 days to reach 50 ‰ mortality, those which are acclimated in 30 ‰ and transferred to 5 ‰ salinity suddenly or gradually take lesser time to attain 50 ‰ mortality. In the same way if animals acclimated in 5 ‰ salinity are transferred gradually to 30 ‰ salinity medium the time to reach 50 ‰ mortality is also less, i.e. 28 days which is lower than 45.5 days in the 30 ‰ salinity acclimation medium. These observations seem to indicate that in the natural surroundings also when salinity changes take place suddenly or gradually due to climatic variations there can be a depletion of population due to adverse effects.

In distilled water the time taken to reach 50 ‰ mortality is only 1.7 days, which shows that they are unable to survive in this medium. So also the media of very high salinities, i.e. 60 ‰, 70 ‰ and 80 ‰ they are unable to tolerate.

# CHAPTER V

## OBSERVATIONS ON THE RESPIRATION OF SPHAEROMA TEREBRANS BATE

### INTRODUCTION

The influence of body weight upon the rate of oxygen consumption in Crustacea has been reported by various workers. In most animals it is generally found that their oxygen uptake per unit time is proportional to some exponential function of the animal's body weight and this is expressed in the form of an 'allometric' equation

$$O_2 = aW^b \quad \text{(Zeuthen, 1953)} \qquad .. \qquad (1) \quad \text{where } b < 1$$

where $O_2$ is the total oxygen consumption in unit time, 'W' is the total body weight and 'a' and 'b' are coefficients. In the logarithmic form of the equation, 'a' represents the intercept on the Y- axis and 'b' the slope of the function. The weight specific oxygen consumption (i.e. $O_2$ /body weight/hr) is expressed in a modified form of the equation

$$\frac{O_2}{W} = aW^{(b-1)} \qquad .. \qquad .. \qquad (2) \quad \text{where } b < 1$$

which shows a decreasing function of the metabolic rate with increasing size and the slope of the logarithmic plot is negative. This type of equation is found to hold good not only to the whole organisms but to the respiration of some, isolated tissues as well.

The total and tissue respiration in Pugettia producta was investigated by Weymouth et al (1944) and have reported that the 'b' value in this species is significantly different from the 'two thirds' value of the 'surface area law'. In Balanus (balanoide?) the 'b' value obtained was similar to those observed in other crustaceans (Zeuthen, 1947) and in Ligia oceanica the value of 'b' did not significantly differ from the 'two thirds' rule (Ellenby, 1951). Zeuthen (1953) comparing his results on marine Crustacea with the other Crustacea, has pointed out that in marine Crustacea "for animals containing less than about 0.1 mg N body nitrogen, the value of 'b' in equation (1) appears to be around 0.95, while

for animals larger than this (i.e. more than 4.0 gm total weight) 'b' is smaller namely 0.8". Scholander et al (1953) have reported that for several tropical Crustacea the 'b' value is 0.85. Studies on Uca pugnax showed that the 'b' value in this species varied from 0.67 to 0.85 at 24°C (Teshian, 1956). It is reported by Subrahmanyam (1957) that the 'b' value in Emerita asiatica is 0.743.

Bertalanffy (1957) made a review on the variations in 'b' value and has stated that "in the various animal classes, three metabolic types, i.e. form of dependence of metabolic rate on body size can be distinguished: proportionality of metabolic rate to surface area, or to weight, or one intermediate between surface area, or to weight, or one intermediate between surface and weight proportionality".

Rao (1958) has reported a 'b' value varying from 0.5 to 1.05 in Metapenaeus monoceros. The 'b' values of Uca pugnax, U.minax and U.pugilator are 0.67, 0.70 and 0.80, respectively (Teal, 1959). A common 'b' value of 0.6667 has been obtained by Barnes and Barnes (1959) for eight species of barnacles, Balanus glandula, B.cariosus, B.rostratus, B.crenatus, Tetraclita squamosa, Pollicipes polymerus, Chthamalus dalli and C.fissus from the Pacific coast of North America.

Welvekamp and Waterman (1960) have stated that for Crustacea the 'b' value is generally between 0.67 and 1.00. In the former case, metabolism is proportional to the body surface as in Asellus, Gammarus, Niphargus, Pachygrapsus and sometimes in Artemia. In the latter case, the metabolism is proportional to the animal's total volume or weight, as it appears to be in insects. In Balanus amphitrite communis (Darwin) the 'b' value is 0.827 (Gampati & Prasada Rao, 1960). In the intertidal crab, Hemigrapsus oregonensis and H.nudus the 'b' value varied from 0.315 to 0.667 as reported by Dehnel (1960). The 'b' value in Penaeus indicus is reported as 0.604 by Subrahmanyam (1962). Eltringham (1965a) studied the rate of respiration in wood-boring isopod, Limnoria and has stated that it is of the order reported for other littoral isopod, Ligia oceanica by Ellenby (1951) and Edney and Spencer (1955). In Lockwood's book (1967), he has briefly dealt with this aspect in various Crustacea.

It is reported by a number of investigators that in some Crustacea the oxygen uptake is influenced by the concentration of the medium in which they live. Schlieper (1929) in his studies on Carcinus maenus has suggested that the increase in the rate of respiration is due to the differences in osmotic work due to change when concentration of the medium varied from the normal to lower or higher levels. Schwabe (1933) supported Schlieper in his studies on the cray fish, Potamobius fluviatilis and later Flemister and Flemister (1951) in their studies on Ocypode albicans have also come to the same view of Schlieper. But Krogh (1939) in his studies on Eriocheir sinensis has stated that the same respiratory rate is reported in 15 ‰ sea water (which is isotonic to the animal), in 32 ‰ sea water (which is hypertonic) and fresh water (which is hypotonic). High rate of respiration is reported for Eriphia spinifrons and Pagurus longicarpus in hypotonic media (von Buddenbrock, 1948). Panikkar and Viswanathan (1948) in their studies on the active regulation of chloride in Metapenaeus monoceros have stated that the increase in oxygen consumption in diluted media may be to some degree a reflection of chloride regulation. Increase in oxygen consumption is reported in Gammarus duebeni as salinity decreased to 5 ‰ or less, and decrease in the rate of consumption when salinity increased above 20 ‰ (Kinne, 1952). In young nauplii of Artemia salina increase in oxygen uptake is reported by Eliassen (1952), but this increase was less perceptible or even absent in larger individuals.

Wikgren (1953) reviewed the phenomenon of osmoregulation and has stated that the difference in oxygen consumption in fresh water as against isotonic media is not attributable to osmotic regulation. In Eriocheir only a very small fraction of the increased oxygen consumption represents the osmotic work done (Potts, 1954). According to Gross (1957) certain crabs (i.e. Pachygrapsus) struggle hard to escape from a much diluted media and the increased oxygen uptake results from increased muscular activity. In Metapenaeus monoceros (Rao, 1958) both marine and brackish water populations, showed increase in the rate of uptake with decrease in the salinity of the medium below that of the habitat. Dehnel (1960) observed increase in the rate of oxygen uptake in Hemigrapsus oregonensis

and H.sudus in diluted media and has stated that the increase is partly due to the increased work to maintain osmotic balance.

Kinne (1963) has stated that sudden changes in environmental conditions like salinity or temperature may cause fluctuations in the overall activity, changes in behaviour and increase or decrease in the metabolic rates of the animals. Eltringham (1965a) found no significant correlation between the respiratory rate and the degree of dilution of the medium in his studies on Limneria.

Another aspect of respiration in aquatic Crustacea is the relationship between the rate of respiration and the availability of oxygen in the environment. In Scyllarides latus and Carcinus maenas the rate of oxygen uptake is independent of the concentration of the gas from 2.5 to 12.0 ml $O_2$ /L (Henze, 1910). Helff (1928) found that Orconectus immunis was able to maintain normal rate when oxygen concentration was much below the air saturation level. Hyman (1929) worked on planarians and echinoderms and reviewed the work done on different animal groups. In gray fish, Cambarus viridis oxygen consumption is normally independent of oxygen tension up to 2.84 ml $O_2$ /L and below this level the rate of uptake gradually decreased (Heistand, 1931). According to Chen (1932) in the fresh water crab, Eriocheir sinensis, the oxygen uptake is dependent on the oxygen tension of 100 to 10 % air saturation below which it begins to show abnormal and irregular responses. In Asellus aquaticus the rate is directly related to the availability of oxygen in the environment (Fox et al, 1935). It is reported by Malouf (1937) that gray fish, Cambarus bartoni and Procambarus clarkii are independent of the oxygen concentration above the air saturation level, but show dependency below this critical level. In Pugettia producta there is a critical level much below the air saturation level (Weymouth et al, 1944).

Thomas (1954) observed in the lobster, Homarus vulgaris the rate of oxygen uptake is proportional to the concentration of the gas in the medium at all levels below that of the atmospheric oxygen pressure. Similar observations have been made on Pseudosquilla ciliata and Gammarus limnaeus by Weel et al (1954) and Krog (1954), respectively. Prosser (1955) distinguished the animals showing some degree of independence as

'regulators' and these dependent as 'adjusters' and in the former they become dependent below critical pressure. According to Marshal and Orr (1958) in Calanus finmarchicus the critical pressure is much below the air saturation (80 %). Marsh crab, Uca pugnax, U.pugilator and Eurytium limosum maintain normal rates with a concentration of oxygen less than 3 % that for air (Teal, 1959). In Oreonectus virilis the rate of oxygen uptake remain unaffected until a critical tension much below atmospheric oxygen tension is reached and below this tension the rate is related to the concentration of the gas (Hiestand, 1931). According to Prasada Rao and Ganapati (1968) the critical level is 2.8 ml $O_2$ /L for Balanus amphitrite amphitrite and 3.5 ml $O_2$ /L for B.tintinnabulum tintinnabulum.

From the foregoing review it is evident that in Crustacea there is a diversity with regard to their size-related respiration and that there are many types which deviate from the general pattern. The review also shows that crustaceans behave differently with regard to their rate of oxygen consumption in various salinity media. The review further shows that various types of respiratory relationships exist in crustaceans in relation to variations in oxygen concentration in the medium.

The above aspects in sphaeromids have not been worked out so far and therefore an attempt has been made in the present studies to investigate these aspects in Sphaeroma terebrans Bate, a wood-boring isopod found abundantly in the Cochin harbour region.

## MATERIAL AND METHODS

Respiratory measurements of Sphaeroma terebrans were made by using a device fabricated in the laboratory. A diagrammatic sketch of the experimental set-up is shown in fig. 9. The apparatus essentially consists of a syringe 'A' graduated up to 50 cc and ungraduated portion above it. This forms the respiratory chamber. The nozzle at the closed end of the respiratory chamber functions as the passage for letting in and out of water, to which is connected a narrow rubber tube 'C' and this can be closed by a pinch-cock 'D'. The rubber tube 'C' has only an internal

FIG.9

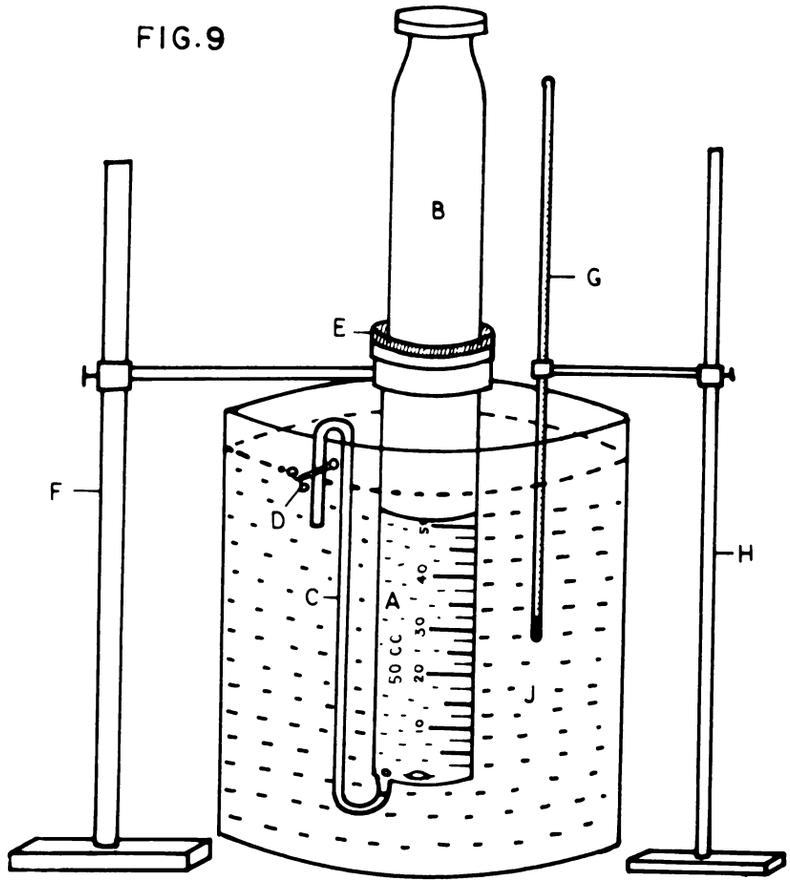
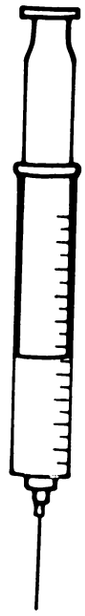



FIG.10

FIG.11



volume of less than 0.5 cc. When the pinch-cock is open, water can be taken in or out of the respiratory chamber by moving the piston 'B' as required. In the vertical position, the pressure due to weight of the piston on the water in the respiratory chamber is nullified by a piston 'catch' 'E'. The whole apparatus is kept in a glass trough 'J' clamped to a stand 'F'. A thermometer 'G' is kept in position in the water trough by means of a stand 'H'. The water in the trough is let in from a waterbath, electrically controlled, and is maintained at 28°C with a variation of ± 1°C, which is the usual temperature in the natural habitat of the animal.

To begin with, a few cc of the water meant for the experiment was drawn into the respiratory chamber 'A' through the rubber tube 'C' by working the piston 'B'. The piston was then removed and the animal kept ready for the experiment was carefully introduced into the respiratory chamber, and again the piston was replaced and pushed down expelling all the air inside the chamber and also a part of the water in it so as to make the chamber free from air bubbles. Afterwards, the chamber was filled with water by working the piston slowly and carefully. Then by pushing the piston the level of water was brought to exactly 50 cc mark. Before the level came to 50 cc mark two water samples of about 10 cc each from the ungraduated portion were taken out through 'C'. After the samples were taken and the level brought to 50 cc mark the pinch-cock was closed and the 'catch' 'E' was fixed to neutralise the pressure of piston on the water in the chamber. Then the apparatus was placed in the trough of water as shown in the fig. 9. The animal moved about for a few seconds and then got into the cavity of the cut-let and remained there. When the samples were taken the animal was got out of the cavity by gently tapping outside the mouth region, but very soon it occupied it again. Up to five water samples of 10 cc each could be drawn from the respirator during the running of one experiment after the animal was allowed to respire.

Out of the two samples taken, one was fixed with Winkler's reagents for estimating the initial oxygen content in the respiratory chamber.

The other sample was kept as a control and was estimated for oxygen at the conclusion of the experiment to find the variation, if any, from the initial level of oxygen. Samples of water from the chamber were drawn out at intervals to estimate oxygen after the animal was allowed to respire. The dissolved oxygen in the samples was estimated using the Winkler's micromethod (Welsh & Smith, 1953). From this, oxygen consumption per hour, as well as oxygen consumption per hour per unit weight of the animal were calculated.

The sampling bottles were of capacity 8 to 9 cc (fig. 10), and 5 cc of the sample was used for titration. The normality of sodium thiosulphate used was about 0.005 and the titration was carried out using 1 cc tubercular syringe (fig. 11) with suitable screwing adjustments, and readings up to an accuracy of 0.005 cc could be taken. The normality of the sodium thiosulphate was verified every time before it was used.

As the rate of respiration depended on the size of the animal and salinity of the medium, the interval between samplings had to be varied, and this was determined by running a few trial experiments as required, when the size varied and medium changed.

The water used for the experiments was filtered with Whatman 42-filter paper and was air saturated to give an oxygen pressure of about 160 mm Hg pressure. Experiments with higher concentrations of oxygen were not attempted, because in the natural environment the animal was not found to experience such conditions. Further, animals kept in laboratory tanks were found to live well in water with the above oxygen pressure. The pH in the acclimation tanks ranged between 7.8 and 8.1.

The water samples of different salinity media for the experiments were prepared either by dilution with distilled water or by evaporation of sea water. The salinity of water samples was determined titrimetrically using silver nitrate by the method described in Barnes (1959).

The wet weight of the animals was determined by weighing them immediately at the end of the experiments to the nearest 0.1 mg after carefully wiping the animals between blotting paper strips.

In order to study the different aspects of respiration during the seasons of low salinity and high salinity, the animals for the low salinity experiments, i.e. in 5 ‰, were collected during rainy season when salinity came very low to 5 ‰ and below, and animals for high salinity experiments, i.e. in 20 ‰, were collected after monsoon period when salinity began to rise to 20 ‰ and above. During this period animals were also collected for experiments in 0 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ salinities to study the influence of variation in salinity on respiration. All the animals for the experiments were collected from timber structures at low-tide level. Pieces of timber with Sphaeroma terebrans were kept in laboratory tanks for 4 to 5 weeks for acclimation before they were used for experiments.

From animals acclimated in the laboratory tanks, some were extracted carefully from their burrows for experiment. As there may be some change when the animals are free, they were kept atleast for 12 hours in clean water of the acclimation salinity fully air saturated before they were used for experiment. This process also helped to get partially cleared their gut. In each experiment only one animal was used at a time, and experiments were repeated several times.

The first series of experiments were conducted to find out the rate of oxygen consumption in a low salinity (5 ‰) and a high salinity (20 ‰) in animals acclimated in the respective medium. Their weight varied from 10.4 mg to 54.3 mg (in 5 ‰ salinity) and 7.0 mg to 74.1 mg (in 20 ‰ salinity). The pH of the experimental media varied from 7.7 to 8.0. The second series of experiments were carried out in media of salinities 0 ‰ (distilled water), 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ on animals acclimated in 20 ‰ salinity in order to find out the effect of sudden variations in salinity, as may be found to occur in the natural environment, on the rate of respiration. As the animals were also found to experience depletion in oxygen concentration in the natural environment and also in the laboratory tanks, the second series of experiments were continued to study the rate of oxygen consumption under depleting oxygen concentration to the lethal level. On an average, 18 animals of varying

size were experimented in each medium. The weight of the animals varied from 0.1 mg to 74.1 mg. Except in distilled water no adjustment of pH of the experimental medium was made. The initial and final pH in all the experiments were measured and it remained within 7.5 and 8.5.

Many workers have investigated the effect of low concentration of oxygen by allowing the animal to exhaust the gas through its own respiration. In such experiments there is an accumulation of carbondioxide and other waste substances which influence the result. Hyman (1925 & 1929) has shown this influence in Planaria. However, Hyman has stated that whether animals respiring in a closed vessel would produce enough carbondioxide to affect their oxygen intake will depend upon the mass of the animal relative to the quantity of water. Amberson and his co-workers (1924) considered the question of the accumulation of carbondioxide and has stated that this factor was not concerned in their results. The method of passing nitrogen through the medium to obtain reduced oxygen concentration (Prasada Rao & Ganapati, 1968) was not tried as the animal is not found to experience abrupt depletion in the oxygen concentration in the natural environment. The limitations of the method employed in the present studies precluded the possibility of eliminating carbondioxide during the course of the experiment.

The following are the titles of the experiments:-

(A) Oxygen consumption in relation to body weight in Sphaeroma terebrans Bate acclimated in 5 ‰ and 20 ‰ salinities.

(B) Oxygen consumption in relation to variations in salinity and body weight in Sphaeroma terebrans Bate acclimated in 20 ‰ salinity.

(C) Oxygen consumption in relation to depleting oxygen concentration, salinity variation and body weight in Sphaeroma terebrans Bate acclimated in 20 ‰ salinity.

Based on the data collected from these experiments, relations between oxygen consumption and body weight were obtained. Least square estimates of parameters involved in the relations were found out.

For the comparison of the regression values obtained in the species under different experimental conditions, the 't' values were calculated

using the method of 'Student's' 't' (Goulden, 1952) for testing the statistical significance.

## RESULTS

### (A) OXYGEN CONSUMPTION IN RELATION TO BODY WEIGHT IN SPHAEROMA TEREBRANS BATE ACCLIMATED IN 5 ‰ AND 30 ‰ SALINITIES.

Oxygen consumption in 5 ‰ salinity:- The oxygen uptake and the metabolic rate in the different sizes of Sphaeroma terebrans are given in table 4 (Page 33). The oxygen consumption and the metabolic rate in 18 different sizes studied, varied from 4.266 µl/hr to 9.183 µl/hr and 410.2 µl/hr/gm to 169.1 µl/hr/gm, respectively, depending upon the size of the animals. The body weight of the animals ranged from 10.4 to 54.3 mg.

The oxygen uptake of these animals increased with increasing body weight. The increase in the oxygen uptake showed an exponential relationship with the increasing body weight. As shown in the fig. 12 when the log oxygen consumption is plotted against the log body weight, it shows a high positive linear relation between the two characters, which may be expressed as:

$$\log O_2 = \log a + b \log W \text{ (or } O_2 = aW^b) \qquad (1)$$

The metabolic rate or the weight specific oxygen consumption, i.e. oxygen uptake per unit body weight in unit time shows a decline with increase in body weight and the log metabolic rate against log body weight (fig. 13) shows a linear negative regression which is of the form:

$$\log O_2 - \log W = \log a + b \log W - \log W \text{ (or } \frac{O_2}{W} = aW^{b-1}) \qquad (2)$$

Using the method of least squares, estimate of regression coefficient 'b' for the total oxygen consumption against body weight for Sphaeroma terebrans acclimated in 5 ‰ salinity in an oxygen pressure of 140 mm Hg is obtained as 0.4469 (which is the value of 'b' in the equation (1) ), the estimate of parameter 'a' is found to be 0.1801 and the regression value for the weight specific oxygen consumption, i.e. $O_2$/gm/hr is negative and is obtained as -0.5537 which is the estimate of 'b-1' value

## TABLE 4

**Oxygen uptake and metabolic rate in Sphaeroma terebrans Bate acclimated in 5 ‰ salinity (values taken from fig.12)**

| Sl. No. | Body wt. in mg | $O_2$ uptake in µl $O_2$/hr | $O_2$ uptake in µl/hr/gm |
|---|---|---|---|
| 1 | 10.4 | 4.266 | 410.2 |
| 2 | 16.0 | 5.120 | 320.6 |
| 3 | 16.9 | 5.248 | 310.6 |
| 4 | 18.3 | 5.496 | 300.2 |
| 5 | 18.6 | 5.559 | 298.8 |
| 6 | 19.8 | 5.754 | 290.6 |
| 7 | 22.5 | 6.026 | 267.8 |
| 8 | 26.5 | 6.310 | 238.1 |
| 9 | 28.5 | 6.761 | 237.2 |
| 10 | 30.5 | 6.918 | 226.9 |
| 11 | 39.5 | 7.943 | 201.0 |
| 12 | 40.0 | 7.943 | 198.6 |
| 13 | 44.9 | 8.318 | 185.2 |
| 14 | 48.6 | 8.710 | 179.3 |
| 15 | 52.4 | 9.016 | 172.1 |
| 16 | 53.6 | 9.120 | 170.1 |
| 17 | 53.7 | 9.120 | 169.8 |
| 18 | 54.3 | 9.183 | 169.1 |

FIG. 12

Relationship of oxygen uptake and body weight in Sphaeroma terebrans in 5 ‰ salinity medium at 140 mm Hg pressure of $O_2$. 'b' value = 0.4463.

FIG. 13

Relationship of metabolic rate and body weight in Sphaeroma terebrans in 5 ‰ salinity medium at 140 mm Hg pressure of $O_2$. 'b-1' value = -0.5537

FIG.12

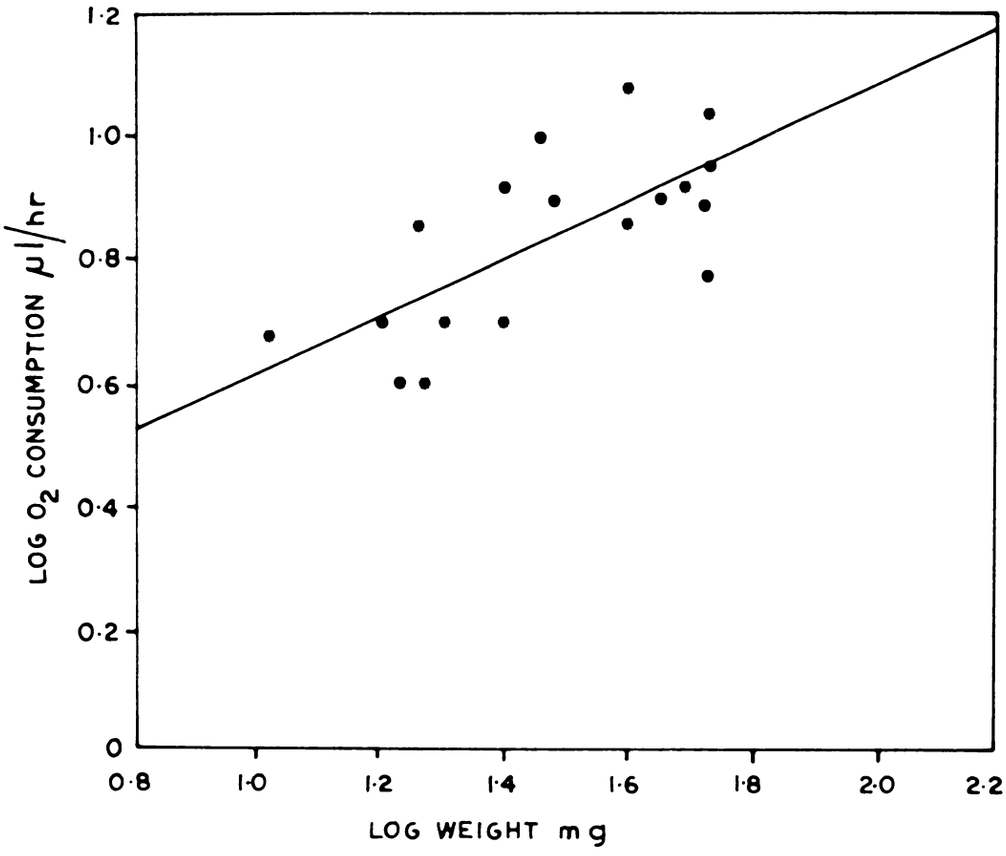
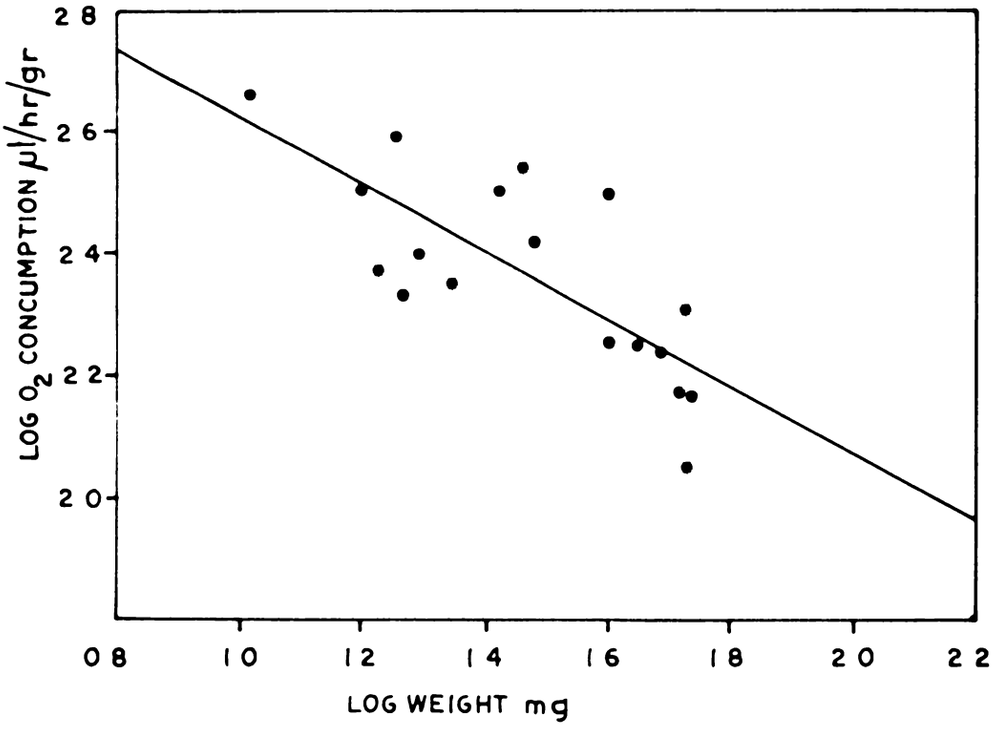

1·2
1·0
0·8
0·6
0·4
0·2
0
LOG $O_2$ CONSUMPTION µl/hr
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
LOG WEIGHT mg

FIG.13


2 8
2 6
2 4
2 2
2 0
LOG $O_2$ CONCUMPTION µl/hr/gr
0 8
1 0
1 2
1 4
1 6
1 8
2 0
2 2
LOG WEIGHT mg

in the equation (2). The regression values, the correlation coefficient, the standard error and the other statistical details are presented in table 5 (Page 35).

Oxygen consumption in 20 ‰ salinity:- The oxygen uptake and the metabolic rate in the different sizes of Sphaeroma terebrans are given in table 6 (Page 36). The oxygen consumption of the animals of different sizes varied from 7.948 µl/hr to 17.99 µl/hr and the metabolic rate from 1134.0 µl/hr/gm to 242.8 µl/hr/gm. The wet weight of the animals ranged from 7.0 to 74.1 mg.

The oxygen consumption showed an increase with increasing size of the animals and the relationship is similar to that of Sphaeroma terebrans acclimated to 5 ‰ salinity. As shown in the fig. 14, the log $O_2$ uptake when plotted against log body weight shows a high linear positive relation and the weight specific metabolism when plotted logarithmically shows a negative linear relation (fig. 15). The characteristics of the regression lines are respectively similar, positive in the $O_2$ uptake and negative in the weight specific figures. The correlations are in the form of 1 and 2 equations respectively as described above in the case of Sphaeroma terebrans acclimated in 5 ‰ salinity.

The regression value obtained for S.terebrans acclimated in 20 ‰ salinity for the total $O_2$ uptake against body weight in an oxygen pressure of 140 mm Hg is 0.3428 which is the value of 'b' in equation (1) and the estimate of 'a' is 0.6104. The weight specific regression value calculated is negative which is -0.6572. This value is the 'b-1' value in the equation (2). The regression values, the correlation coefficient, the standard error and the other statistical details are presented in table 5 (Page 35).

The regression coefficients obtained in 5 ‰ and 20 ‰ salinities were statistically analysed and it was found that the difference between them is not significant.

## TABLE 5

**Showing regression coefficients, correlation coefficients, standard errors, 't' values of 'b' and its probabilities of weight specific metabolism of Sphaeroma terebrans.**

| Acclimation salinity | No | b | b-1 | r | $S_b$ | $t_b$ | P | - |
|---|---|---|---|---|---|---|---|---|
| 5 ‰ | 18 | 0.4463 | -0.5537 | 0.69 | 0.1173 | 3.805 | 0.001 to 0.01 | $t_{b1 - b2}$ = 0.4743 |
| 20 ‰ | 18 | 0.3428 | -0.6572 | 0.65 | 0.1009 | 3.393 | 0.001 to 0.01 | $P_{b1 - b2}$ = 0.5 to 0.7 |

T A B L E 6

Oxygen uptake and metabolic rate in Sphaeroma terebrans Bate acclimated in 20 ‰ salinity (values taken from fig. 14)

| Sl. No. | Body wt. mg. | $O_2$ uptake in µl $O_2$/hr | $O_2$ uptake in µl/hr/gm |
|---|---|---|---|
| 1 | 7.0 | 7.943 | 1134.0 |
| 2 | 14.7 | 10.230 | 696.1 |
| 3 | 17.2 | 10.840 | 633.1 |
| 4 | 17.5 | 10.840 | 619.4 |
| 5 | 19.0 | 11.220 | 590.5 |
| 6 | 22.1 | 11.750 | 531.6 |
| 7 | 22.2 | 11.780 | 530.4 |
| 8 | 26.3 | 12.590 | 478.6 |
| 9 | 27.1 | 12.740 | 469.9 |
| 10 | 28.9 | 12.880 | 460.1 |
| 11 | 39.7 | 14.450 | 364.1 |
| 12 | 40.4 | 14.620 | 361.9 |
| 13 | 42.3 | 14.790 | 349.7 |
| 14 | 42.3 | 14.790 | 349.7 |
| 15 | 45.5 | 15.140 | 332.7 |
| 16 | 56.3 | 16.220 | 288.0 |
| 17 | 57.5 | 16.410 | 285.3 |
| 18 | 74.1 | 17.990 | 242.8 |

FIG. 14

Relationship of oxygen uptake and body weight in *Sphaeroma terebrans* in 20 ‰ salinity medium at 140 mm Hg pressure of $O_2$. 'b' value = 0.3428.

FIG. 15

Relationship of metabolic rate and body weight in *Sphaeroma terebrans* in 20 ‰ salinity medium at 140 mm Hg pressure of $O_2$. 'b-1' value = -0.6572.

FIG.14

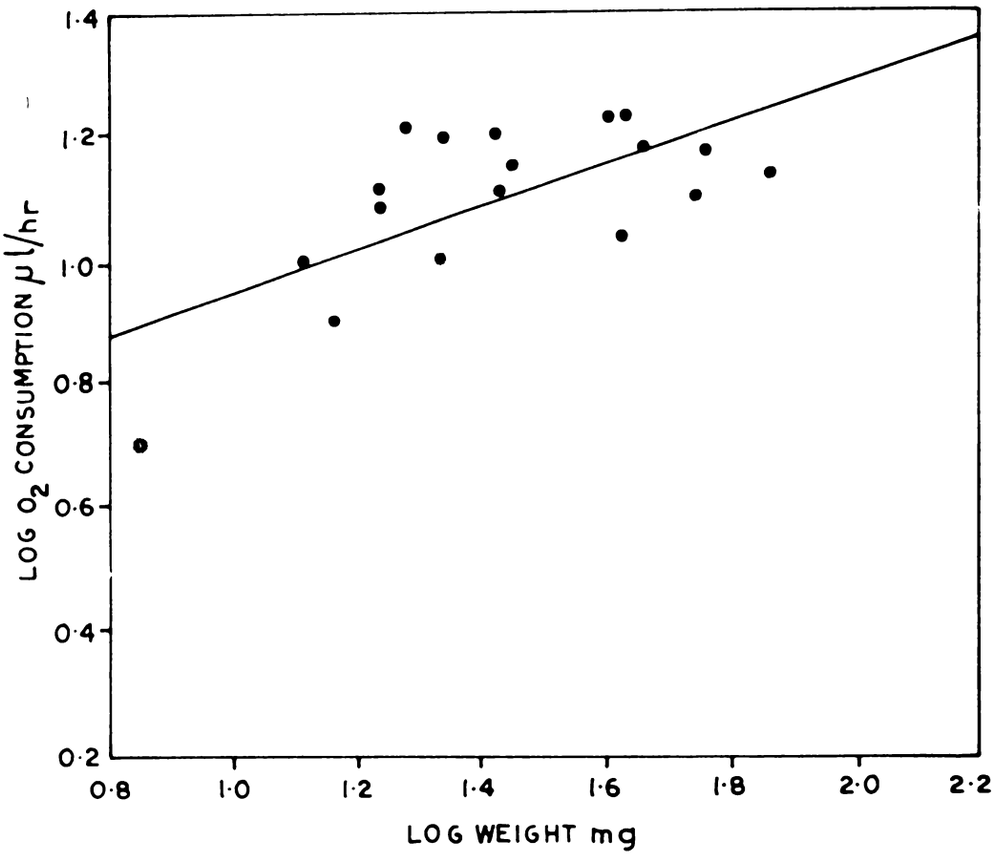
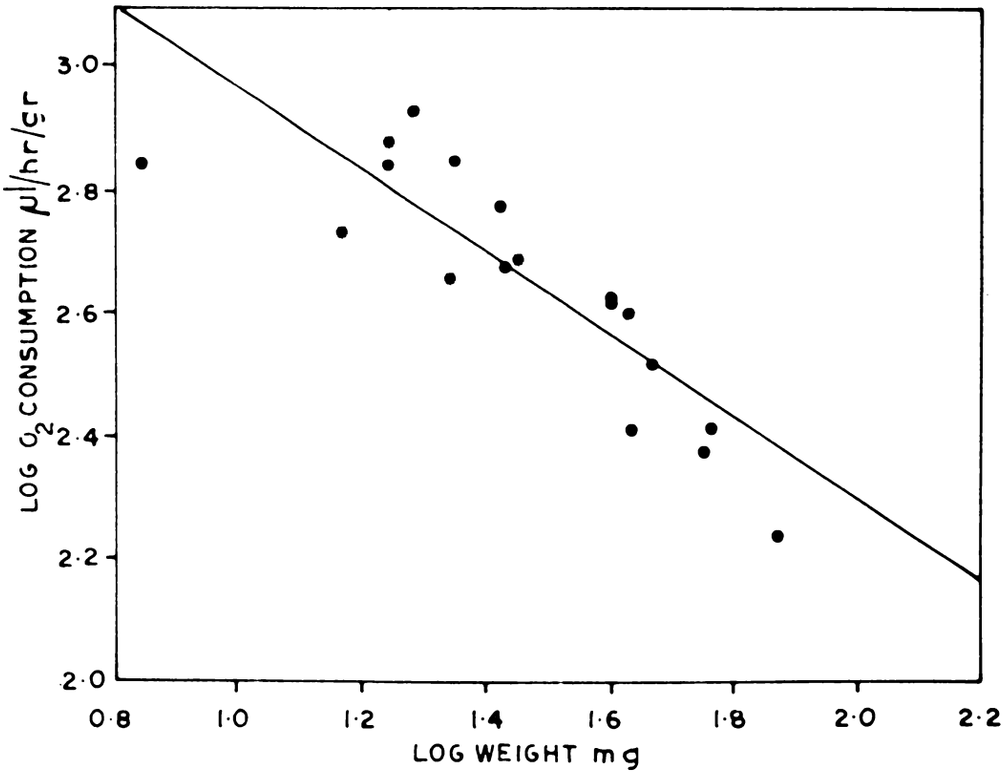

LOG $O_2$ CONSUMPTION µl/hr
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
LOG WEIGHT mg

FIG.15


LOG $O_2$ CONSUMPTION µl/hr/gr
3·0
2·8
2·6
2·4
2·2
2·0
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
LOG WEIGHT mg

## (B) OXYGEN CONSUMPTION IN RELATION TO VARIATIONS IN SALINITY AND BODY WEIGHT IN SPHAEROMA TEREBRANS BATE ACCLIMATED IN 20 ‰ SALINITY.

Oxygen consumption in 0 ‰ salinity (i.e. distilled water):- The oxygen consumption and metabolic rate in 16 different sizes of animals studied, varied from 6.026 µl/hr to 7.674 µl/hr and 590.7 µl/hr/gm to 149.0 µl/hr/gm, respectively, depending upon the size of the animals. The body weight of the animals varied from 10.2 mg to 51.3 mg. The regression value obtained for the species in 0 ‰ salinity for the total oxygen uptake against body weight is 0.1350 at 140 mm Hg pressure of $O_2$ which is the value of 'b' in equation (1) given on page 22 and see fig. 16. The weight specific regression value calculated is negative -0.8650 and this is the 'b-1' value in equation (2) given on page 22.

Oxygen consumption in 1 ‰ salinity:- The oxygen consumption and metabolic rate in 1 ‰ salinity in the 22 nos. of different sizes of animals experimented varied from 2.317 µl/hr to 13.03 µl/hr and 275.9 µl/hr/gm to 179.3 µl/hr/gm, respectively, depending upon the size of the animals. The body weight of the animals varied from 8.4 to 72.7 mg. Using the same methods and equations mentioned earlier the 'b' value and the 'b-1' value were found out and they are 0.7927 (fig. 16) and -0.2073, respectively.

Oxygen consumption in 5 ‰ salinity:- The rate of oxygen consumption and metabolic rate in 18 animals whose weight varied from 7.4 to 73.0 mg were studied in this salinity. Their rate of oxygen consumption varied from 2.018 µl/hr to 11.480 µl/hr and metabolic rate from 272.8 µl/hr/gm to 157.3 µl/hr/gm depending upon the size of the animals. The 'b' value and 'b-1' value obtained are 0.7511 (fig. 16) and -0.2489, respectively.

Oxygen consumption in 10 ‰ salinity:- In this salinity medium 21 animals of weight varying from 6.1 to 70.0 mg were experimented. Their oxygen consumption and metabolic rate varied from 1.567 µl/hr to 14.29 µl/hr and 256.8 µl/hr/gm to 204.1 µl/hr/gm, respectively. The 'b' and 'b-1'

FIG.16

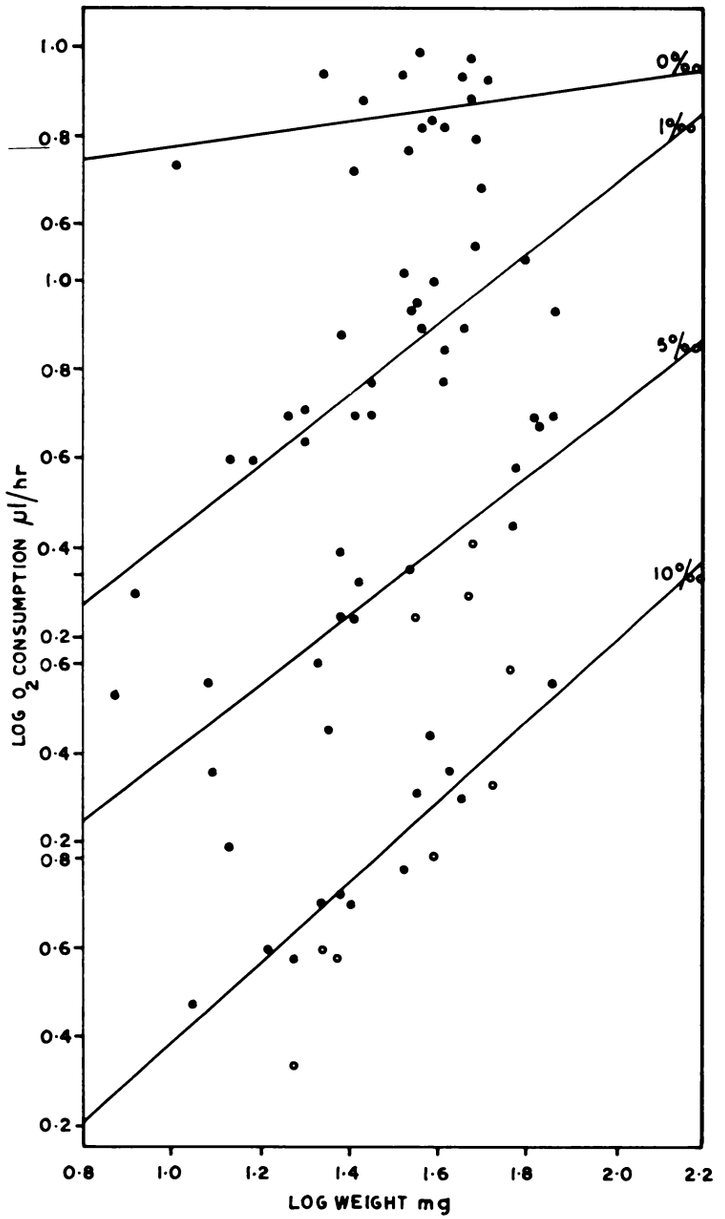
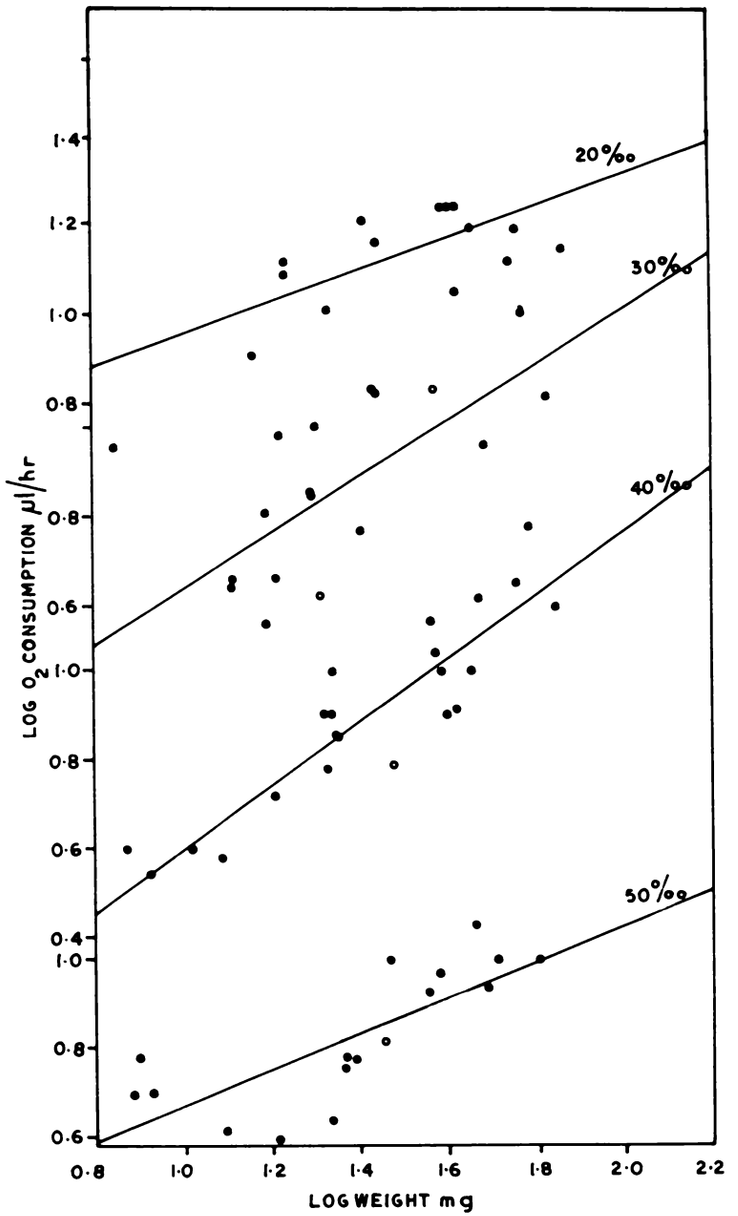

0‰
1‰
5‰
10‰
LOG $O_2$ CONSUMPTION µl/hr
LOG WEIGHT mg

FIG.17


20‰
30‰
40‰
50‰
LOG $O_2$ CONSUMPTION µl/hr
LOG WEIGHT mg

values obtained are 0.9092 (fig. 16) and -0.0908, respectively.

Oxygen consumption in 20 ‰ salinity:- Eighteen animals whose weight varied from 7.0 to 74.1 mg were studied in this series. Oxygen consumption and metabolic rate in this series varied from 7.943 µl/hr to 17.99 µl/hr and 1134.0 µl/hr/gm to 242.8 µl/hr/gm, respectively. The values of 'b' and 'b-1' are 0.3428 (fig. 17) and -0.6572, respectively.

Oxygen consumption in 30 ‰ salinity:- The rate of oxygen consumption and metabolic rate varied from 2.851 µl/hr to 14.13 µl/hr and 559.0 µl/hr/gm to 208.4 µl/hr/gm, respectively in this series. Altogether 18 animals whose body weight varying from 6.1 to 67.8 mg were used for the experiment. The 'b' value obtained is 0.6077 (fig. 17) and the 'b-1' value -0.3923.

Oxygen consumption in 40 ‰ salinity:- In this medium 17 animals were used for the experiment; weight varied from 7.7 to 62.4 mg. Their rate of oxygen consumption varied from 3.199 µl/hr to 16.22 µl/hr and metabolic rate from 432.3 µl/hr/gm to 235.1 µl/hr/gm. The value of 'b' calculated is 0.7080 (fig. 17) and 'b-1' is -0.2920.

Oxygen consumption in 50 ‰ salinity:- Seventeen animals of weight varying from 7.7 to 62.4 mg were experimented in this medium. Oxygen consumption and metabolic rate varied from 4.241 µl/hr to 10.00 µl/hr and 550.8 µl/hr/gm to 160.3 µl/hr/gm, respectively. The value of 'b' is found to be 0.4094 (fig. 17) and of 'b-1' -0.5906.

The regression values, the correlation coefficients, the standard errors and other statistical details are presented in table 7 (Page 39). High correlation values are obtained for the total oxygen consumption and the body weight in the various test salinities, except in 0 ‰ salinity, in this species.

The regression coefficients obtained in 0 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ salinities were statistically analysed and the details are presented in table 8 (Page 40).

## TABLE 7

**Showing the results of the statistical analysis of the regression coefficients obtained for Sphaeroma terebrans in different salinity media under 140 mm Hg pressure of oxygen.**

| Sl. No. | Salinity medium ‰ | No. | b | r | $S_b$ | $t_b$ | P |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 16 | 0.1250 | 0.20 | 0.1693 | 0.7974 | 0.3 to 0.5 |
| 2 | 1 | 22 | 0.7927 | 0.87 | 0.1003 | 7.903 | < 0.001 |
| 3 | 5 | 18 | 0.7511 | 0.86 | 0.1107 | 6.785 | < 0.001 |
| 4 | 10 | 21 | 0.9092 | 0.89 | 0.1090 | 8.339 | < 0.001 |
| 5 | 20 | 18 | 0.3428 | 0.65 | 0.1009 | 3.393 | 0.001 to 0.01 |
| 6 | 30 | 19 | 0.6077 | 0.81 | 0.1070 | 5.680 | < 0.001 |
| 7 | 40 | 22 | 0.7080 | 0.91 | 0.2322 | 3.050 | 0.001 to 0.01 |
| 8 | 50 | 17 | 0.4094 | 0.78 | 0.0856 | 4.783 | < 0.001 |

## TABLE 8

**Showing comparison of regression coefficients obtained under 140 mm Hg pressure of oxygen in different media.**

| Sl. No. | Comparing media % | Probability |
|---|---|---|
| 1 | 20 and 0 | N.S.* |
| 2 | 20 and 1 | 0.02 - 0.05 |
| 3 | 20 and 5 | N.S. |
| 4 | 20 and 10 | < 0.01 |
| 5 | 20 and 30 | N.S. |
| 6 | 20 and 40 | N.S. |
| 7 | 20 and 50 | N.S. |
| 8 | 0 and 1 | 0.01 - 0.02 |
| 9 | 0 and 5 | 0.02 - 0.05 |
| 10 | 0 and 10 | < 0.01 |
| 11 | 0 and 30 | N.S. |
| 12 | 0 and 40 | N.S. |
| 13 | 0 and 50 | N.S. |
| 14 | 1 and 5 | N.S. |
| 15 | 1 and 10 | N.S. |
| 16 | 1 and 30 | N.S. |
| 17 | 1 and 40 | N.S. |
| 18 | 1 and 50 | 0.02 - 0.05 |
| 19 | 5 and 10 | N.S. |
| 20 | 5 and 30 | N.S. |
| 21 | 5 and 40 | N.S. |
| 22 | 5 and 50 | N.S. |
| 23 | 10 and 30 | N.S. |
| 24 | 10 and 40 | N.S. |
| 25 | 10 and 50 | 0.01 |
| 26 | 30 and 40 | N.S. |
| 27 | 30 and 50 | N.S. |
| 28 | 40 and 50 | N.S. |

* N.S. not significant.

## (C) OXYGEN CONSUMPTION IN RELATION TO DEPLETING OXYGEN CONCENTRATION, SALINITY VARIATION AND BODY WEIGHT IN SPHAEROMA TERRERANS RATE IN 20 ‰ SALINITY.

The rate of respiration under different oxygen concentrations in various salinities for animals of weight 15, 30, 45 and 60 mg are presented in table 9 (Page 42). The regression values were calculated for the various pressures in different salinities and are presented in figs. 18 - 25.

Rate of respiration in 140 mm Hg pressure:- The rate of respiration in 0 ‰ salinity varied from 6.457 to 7.943 µl/hr; in 1 ‰ salinity 3.715 to 11.22 µl/hr; in 5 ‰ salinity 3.508 to 10.00 µl/hr; in 10 ‰ salinity 3.548 to 12.30 µl/hr; in 20 ‰ salinity 10.23 to 16.60 µl/hr; in 30 ‰ salinity 5.559 to 13.03 µl/hr; in 40 ‰ salinity 5.370 to 14.45 µl/hr and in 50 ‰ salinity 5.559 to 9.772 µl/hr. The regression values obtained in different media varied from 0.1350 (in 0 ‰ salinity) to 0.9092 (in 10 ‰ salinity).

Rate of respiration in 120 mm Hg pressure:- Except for that in 0 ‰, all the rates are the same as that obtained in 140 mm Hg pressure. In 0 ‰ salinity the rate increased to 6.607 µl/hr in 15 mg animals and it decreased to 7.079, 7.413 and 7.586 µl/hr in 30, 45 and 60 mg animals, respectively. The regression values varied from 0.1126 (in 0 ‰ salinity) to 0.9092 (in 10 ‰ salinity).

Rate of respiration in 100 mm Hg pressure:- In 0 ‰ salinity the rate varied from 5.754 to 6.607 µl/hr; in 1 ‰ salinity 3.548 to 11.89 µl/hr; in 5 ‰ salinity 3.508 to 10.00 µl/hr; in 10 ‰ salinity 3.508 to 12.30 µl/hr; in 20 ‰ salinity 10.00 to 16.08 µl/hr; in 30 ‰ salinity 5.012 to 12.02 µl/hr; in 40 ‰ salinity 5.129 to 13.96 µl/hr; in 50 ‰ salinity 5.012 to 9.016 µl/hr, respectively. The regression values varied from 0.1080 (in 0 ‰ salinity) to 0.9042 (in 10 ‰ salinity).

Rate of respiration in 80 mm Hg pressure:- In 0 ‰ salinity most of the animals died before reaching a concentration as low as 80 mm Hg pressure. In 1 ‰ salinity the rate varied from 2.692 to 11.35 µl/hr; in 5 ‰ salinity

## TABLE 9

**Showing the rate of oxygen consumption under varying oxygen concentration in different salinity media for animals of weight 15 mg, 30 mg, 45 mg and 60 mg.**

| Sl. No. | Wt. of animals mg. | $O_2$ Concentration mm Hg | $O_2$ consumption in µl $O_2$ /hr | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Salinities ‰. | | | | | | | |
| | | | 0 | 1 | 5 | 10 | 20 | 30 | 40 | 50 |
| | | 140 | 6.457 | 3.715 | 3.508 | 3.548 | 10.23 | 5.559 | 5.370 | 5.559 |
| | | 120 | 6.607 | 3.715 | 3.508 | 3.548 | 10.23 | 5.559 | 5.370 | 5.559 |
| 1 | 15 | 100 | 5.754 | 3.548 | 3.508 | 3.508 | 10.00 | 5.012 | 5.129 | 5.012 |
| | | 80 | — | 2.692 | 2.630 | 3.055 | 8.414 | 3.846 | 3.846 | 3.508 |
| | | 60 | — | 1.820 | 1.660 | 2.204 | 5.495 | 2.754 | 2.213 | 2.692 |
| | | 140 | 7.161 | 6.457 | 5.957 | 6.607 | 13.03 | 8.610 | 8.810 | 7.413 |
| | | 120 | 7.079 | 6.457 | 5.957 | 6.607 | 13.03 | 8.610 | 8.810 | 7.413 |
| 2 | 30 | 100 | 6.166 | 6.457 | 5.957 | 6.531 | 12.74 | 7.762 | 8.511 | 6.683 |
| | | 80 | — | 5.559 | 4.955 | 5.689 | 10.84 | 6.237 | 6.761 | 5.018 |
| | | 60 | — | 3.951 | 3.508 | 4.266 | 7.442 | 4.416 | 4.266 | 3.273 |
| | | 140 | 7.586 | 8.810 | 7.943 | 9.441 | 14.96 | 10.84 | 11.61 | 8.710 |
| | | 120 | 7.413 | 8.810 | 7.943 | 9.441 | 14.96 | 10.84 | 11.61 | 8.710 |
| 3 | 45 | 100 | 6.457 | 9.120 | 7.943 | 9.226 | 14.45 | 10.00 | 11.21 | 7.952 |
| | | 80 | — | 8.318 | 7.079 | 8.035 | 12.59 | 8.222 | 9.333 | 6.310 |
| | | 60 | — | 6.095 | 5.309 | 6.166 | 9.441 | 5.888 | 5.495 | 3.631 |
| | | 140 | 7.943 | 11.22 | 10.00 | 12.30 | 16.60 | 13.03 | 14.45 | 9.772 |
| | | 120 | 7.586 | 11.22 | 10.00 | 12.30 | 16.60 | 13.03 | 14.45 | 9.772 |
| 4 | 60 | 100 | 6.607 | 11.89 | 10.00 | 12.30 | 16.03 | 12.02 | 13.96 | 9.016 |
| | | 80 | — | 11.35 | 9.333 | 10.59 | 14.13 | 10.12 | 11.89 | 7.413 |
| | | 60 | — | 8.502 | 7.244 | 8.128 | 10.96 | 7.244 | 8.318 | 3.981 |

FIG.18

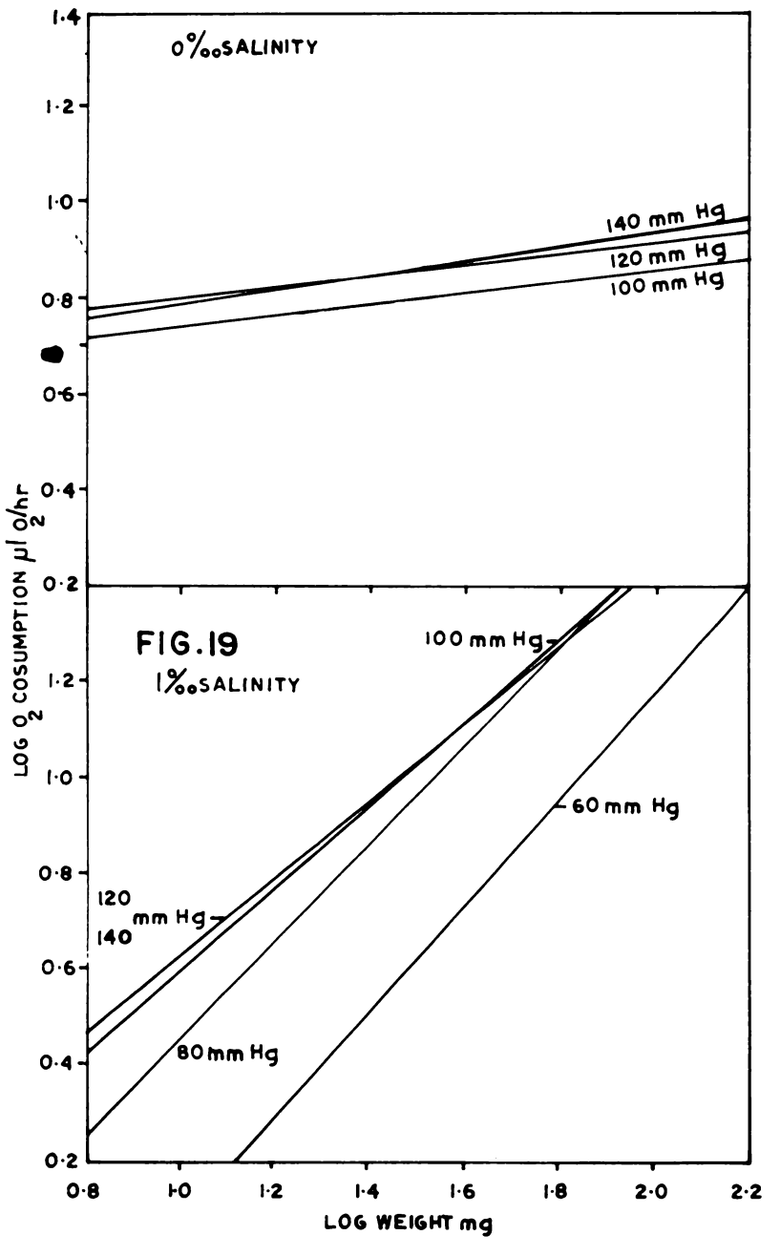



FIG.19

FIG.20

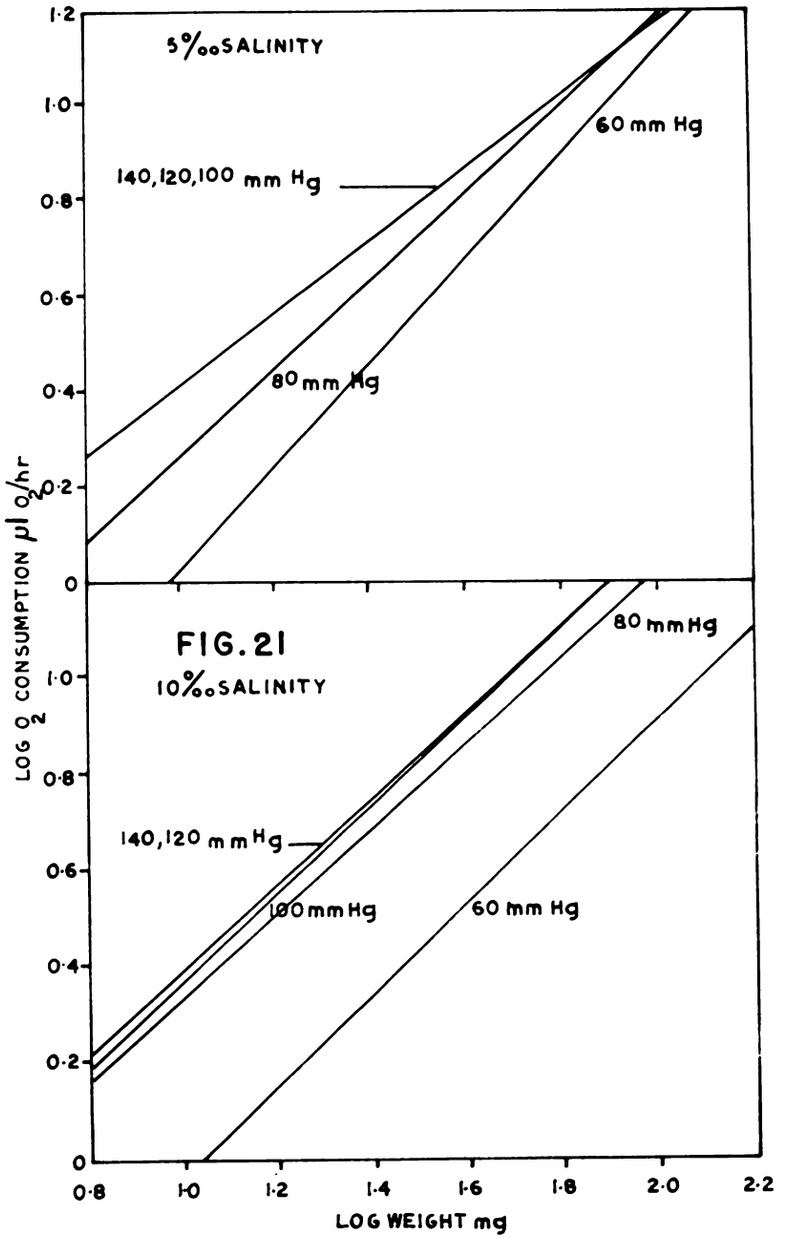



FIG.21

FIG.22

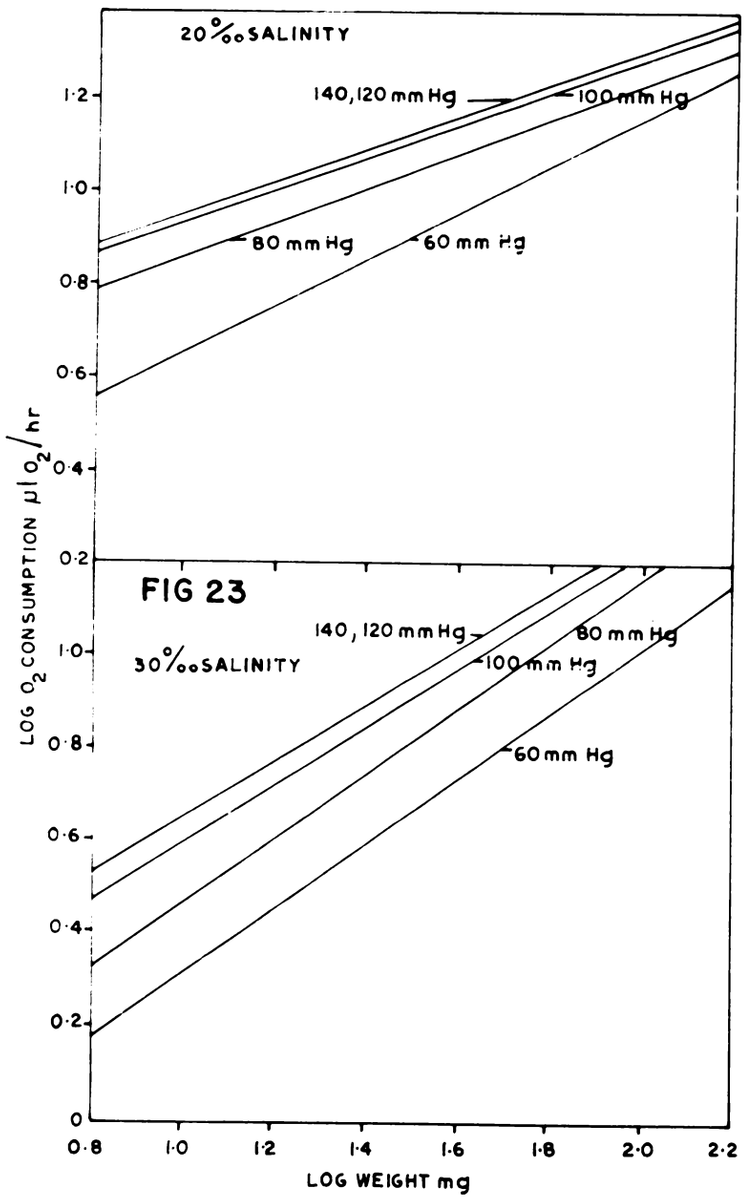



FIG 23




FIG.24

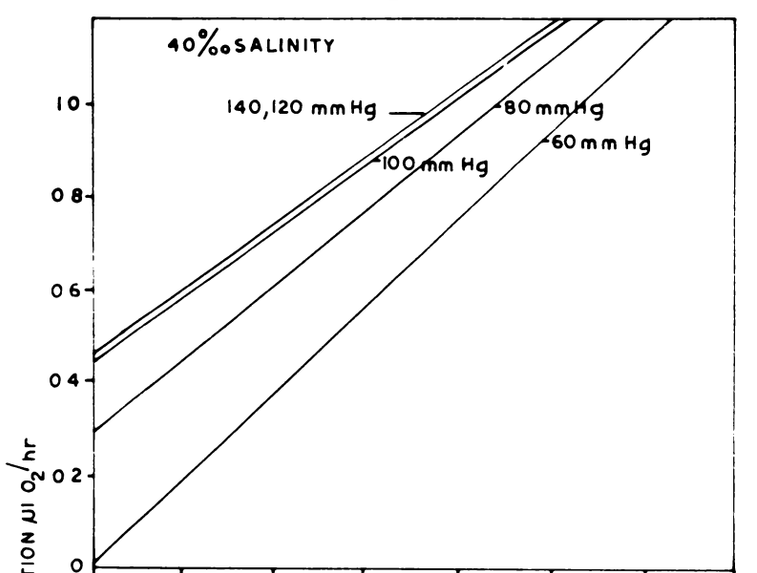
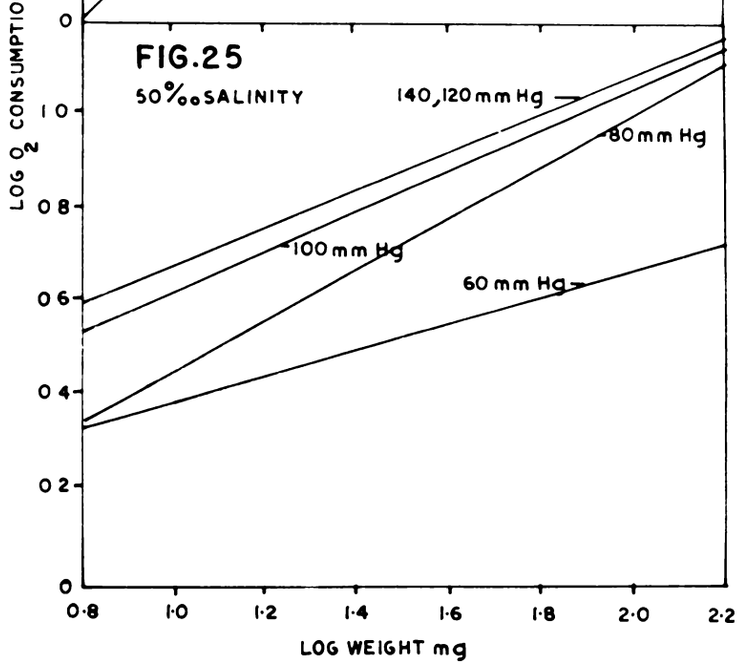



FIG.25



2.630 to 9.333 µl/hr; in 10 ‰ salinity 3.055 to 10.59 µl/hr; 20 ‰ salinity 8.414 to 14.13 µl/hr; 30 ‰ salinity 3.846 to 10.12 µl/hr; in 40 ‰ salinity 3.846 to 11.89 µl/hr; in 50 ‰ salinity 3.508 to 7.413 µl/hr, respectively. The regression values changed from 0.3629 (in 20 ‰ salinity) to 1.0272 (in 1 ‰ salinity).

Rate of respiration in 60 mm Hg pressure:- In 0 ‰ salinity no readings could be obtained for reasons mentioned in the preceding para. In 1 ‰ salinity the rate varied from 1.820 to 8.502 µl/hr; in 5 ‰ salinity 1.660 to 7.244 µl/hr; in 10 ‰ salinity 2.204 to 8.128 µl/hr; in 20 ‰ salinity 5.495 to 10.96 µl/hr; in 30 ‰ salinity 2.754 to 7.244 µl/hr; in 40 ‰ salinity 2.213 to 8.818 µl/hr; and in 50 ‰ salinity 2.692 to 3.981 µl/hr, respectively. The highest regression value obtained is 0.9357 in 10 ‰ salinity and the lowest 0.2835 in 50 ‰ salinity.

Lethal level of oxygen content:- In each experiment the volume of dissolved oxygen in the experimental medium at the time of death of animal was noted and expressed as the lethal level for the animal in the particular medium. The observed lethal values of oxygen in the different salinity media for all the animals were statistically analysed to find out its relationship in the different sizes of animals and its variation in the different salinity media. Results obtained in the analysis are presented in table 10 (Page 44) and figs. 26, 27 and 30-37.

## DISCUSSION

(A) Oxygen consumption in relation to body weight:-

The results show that the rate of oxygen consumption in Sphaeroma terebrans acclimated to 5 ‰ and 20 ‰ salinities varied with the size of the animal. The total oxygen consumption of small animals is less than that of large ones, but the metabolic rate or the oxygen consumption per hour per unit weight is more in the former. The total oxygen consumption in S. terebrans acclimated to 5 ‰ salinity varied with size and it increased with 0.4463 power of the body weight and the weight specific oxygen consumption with -0.5537 power of the body weight in 140 mm Hg pressure of oxygen. In S. terebrans acclimated to 20 ‰ salinity,

## TABLE 10

**Showing the results of the statistical analysis of the regression coefficients obtained for *Sphaeroma terebrans* in different salinity media for its lethal level of oxygen.**

| Sl. No. | Salinity medium ‰ | No. of samples | b | r | $S_b$ | $t_b$ | P |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 20 | -0.0338 | -0.3120 | 0.02428 | 1.392 | 0.1 to 0.2 |
| 2 | 1 | 22 | -0.00918 | -0.3670 | 0.005206 | 1.763 | 0.05 to 0.1 |
| 3 | 5 | 21 | -0.00033 | -0.7020 | 0.001075 | 0.3045 | 0.7 to 0.8 |
| 4 | 10 | 21 | -0.00368 | -0.3020 | 0.001353 | 2.718 | 0.01 to 0.02 |
| 5 | 20 | 23 | +0.001162 | +0.1604 | 0.001561 | 0.744 | 0.4 to 0.5 |
| 6 | 30 | 20 | -0.004484 | -0.3201 | 0.001643 | 2.729 | 0.01 to 0.02 |
| 7 | 40 | 24 | -0.005847 | -0.4093 | 0.00277 | 2.110 | 0.02 to 0.05 |
| 8 | 50 | 20 | -0.004454 | -0.4091 | 0.00232 | 1.919 | 0.05 to 0.1 |

FIG. 26

Showing the relationship between body weight and lethal level of oxygen content in the different salinity media.

FIG. 27

Showing variations in the lethal level of oxygen in different salinity media.

FIG.26

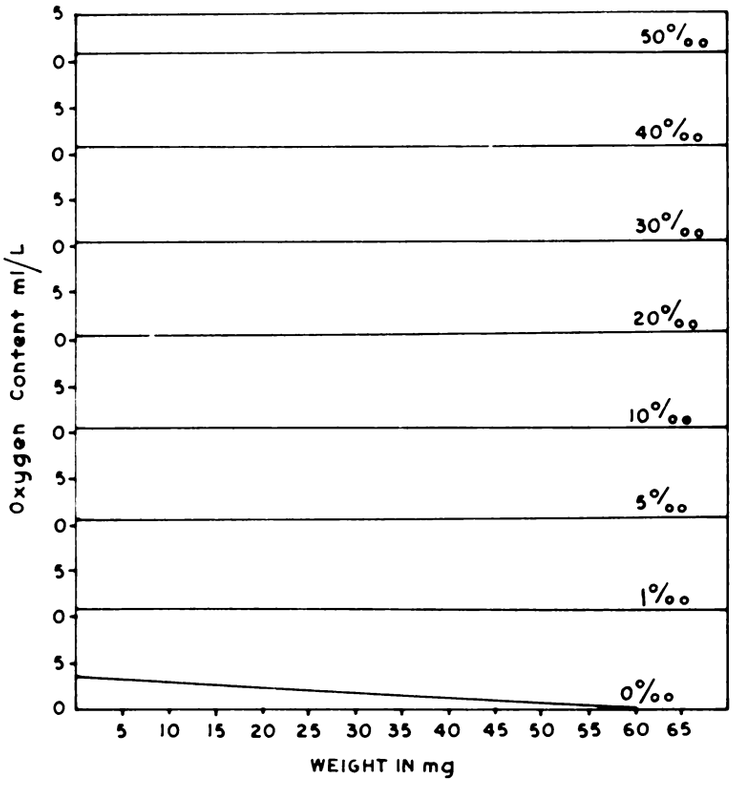
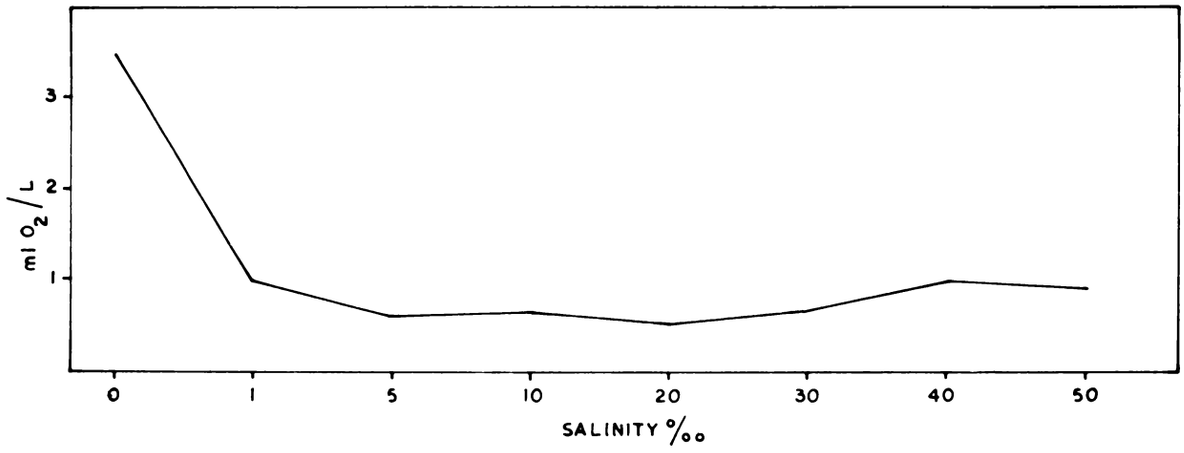

Oxygen Content ml/L
5
0
5
0
5
0
5
0
5
0
5
0
5
0
5
0
50‰
40‰
30‰
20‰
10‰
5‰
1‰
0‰
5 10 15 20 25 30 35 40 45 50 55 60 65
WEIGHT IN mg

FIG.27


ml O2/L
3
2
1
0 1 5 10 20 30 40 50
SALINITY ‰

the total oxygen consumption increased with 0.3428 power of the body weight and the weight specific oxygen consumption with -0.6572.

The value of 'b' 0.4463 of S.terebrans acclimated in 5 ‰ salinity and the value of 'b' 0.3428 of S.terebrans acclimated in 20 ‰ show a departure from the 'two thirds' power of body weight of the 'Surface law'. From the above two values of 'b' obtained for the same species acclimated to two different salinity media it is evident that the oxygen consumption in the animals acclimated in 5 ‰ salinity does not vary with the same power of body weight, and increases with a higher power of function. However, the 't' value (Table 5, page 35) shows that the weight specific regression values of -0.5537 of S.terebrans acclimated in 5 ‰ salinity is not significantly different from -0.6572 of the same species acclimated to 20 ‰ salinity.

It is not easy to compare the present values with the 'b' values reported in Crustacea by various workers owing to the differences in the experimental techniques employed, factors selected for the experiments and also due to the differences in the environmental conditions from where the animals were collected for experimentation. Therefore, it becomes obvious that only a rough comparison is possible. A scrutiny of some of the works reported on crustaceans will show that the 'b' value in Crustacea varies from the generally accepted 'two thirds' value of the 'Surface area law'. While Roberts (1957), Teal (1959), Bertalanffy (1957), Barnes & Barnes (1959), Muller (1943), Will (1952) and Subrahmanyam (1962) have reported that in Pachygrapsus crassipes, Uca pugnax, Daphnia pulex, Artemia salina, Asellus aquaticus, Oniscus asellus, Gammarus sp., Astacus sp., Balanus glandula, B.cariosus, B.rostratus, B.crenatus, Tetraclita squamosa, Pollicipes polymerus, Chthamalus dalli, C.fissus, Armadillidium pallasii, Asellus aquaticus and Penaeus indicus obey the surface rule, the 'b' value for Potamobius torrentium is approximately 1.0 showing that for this animal the metabolic rate is directly perportional to the body weight. However, in Oniscus asellus, Porcellio scaber, Ligia oceanica, Pagettia producta, Emerita asiatica, Uca minax, U.pugilator and Balanus amphitrite communis the 'b' value is reported to be between 0.67 and 1.0 (Will, 1952; Subrahmanyam, 1957; Teal, 1959 and Ganapati &

Prasada Rao, 1960).

In the present studies the 'b' values obtained for Sphaeroma terebrans are 0.4463 in 5 ‰ salinity and 0.3428 in 20 ‰ salinity and obviously these values cannot be included into any of the above three groups as they are comparatively low values. Such low values are very scarcely known in Crustacea. Dehmel (1960) in his investigations on two intertidal crabs, Hemigrapsus oregonensis and H.nudus obtained 'b' values varying from 0.315 to 0.667 and he has stated that only very few values approached the generally known 0.66 or 0.75 exponent. A comparison of the present values with those of Dehmel will show that the values in S.terebrans in both acclimation media fall well within the range reported by him.

Rao (1958) has reported that in Metapenaeus monoceros the 'b' value varied from 0.5 to 1.05. Even though the values obtained in S.terebrans do not reach the higher range reported by Rao, the value 0.4463 obtained in S.terebrans in 5 ‰ salinity is not significantly different from the lowest value of 0.5 observed by him. Subrahmanyam (1962) has reported the 'b' value for Penaeus indicus as 0.604, but in fig. 2 on page 156 of his publication it is found that in this species the 'b' value varied with partial pressure of oxygen. It was 0.43 at 180 and 150 mm Hg pressures, 0.45 at 100 mm Hg pressure and 0.33 at 75 mm Hg pressure. The values 0.43 and 0.45 are very close to the value of 0.4463 obtained in S.terebrans in 5 ‰ salinity and the value 0.33 is very near to the value 0.3428 obtained in 20 ‰.

Sphaeroma terebrans being an isopod it will be of interest to compare the 'b' values of this species with those of other isopods. The 'b' values in isopods Armadillidium pallasii, Asellus aquaticus, Ligia oceanica, Oniscus asellus and Porcellio scaber have been reported by various workers. Muller (1943) has reported that the 'b' value of Armadillidium pallasii is 0.67 at 21°C. He has also reported that in Asellus aquaticus the 'b' value is 0.67 at 20°C. Will (1952) found out the 'b' value of Asellus aquaticus as 0.65 at 23°C. He has also reported the 'b' value of Oniscus asellus as 0.72 at 23°C and of Porcellio scaber

as 0.83 at 23°C. Ellenby (1951), in his studies on Ligia oceanica, a littoral isoped, has reported that the total oxygen consumption in the species was proportional to the 0.726 power of body weight at 25°C and that this value was not statistically different from 0.66. Eltringham (1965a) though conducted studies on the respiration of Limnoria, an wood-boring isoped, no 'b' value has been reported by him. However, he has stated that in Limnoria the weight dependent respiration is of the order reported for Ligia oceanica by Ellenby (1951), and Edney and Spencer (1955). A comparison of the 'b' values of isopods referred to above with these obtained in Sphaeroma terebrans acclimated in 5 ‰ and 20 ‰ salinities in the present investigation will show that they are significantly different from the above values.

The above discussion on the 'b' values in Crustacea and isopods in particular, seems to suggest that the generally known or accepted 'b' values 0.67 to 1.0 in Crustacea can no more be given such significance as it was considered earlier. The present results also seem to suggest that it is difficult to assign a particular 'b' value to animals under a particular group and sometimes even to a particular species as it depends upon the past environmental conditions of the animal as well as experimental factors to which the animal is exposed.

Statistical analysis has shown that the 'b' values 0.4463 in 5 ‰ salinity and 0.3428 in 20 ‰ salinity obtained in the present studies are not significantly different. This shows that in S. terebrans living in high and low salinity media, their weight specific metabolism is not much different. In other words, the present studies have shown the existence of similar metabolic types living in two different salinity environments.

Thus in the present studies similar metabolic types living in two different environments can be observed within the same species and whose 'b' values are significantly lower than the values generally known.

For reasons mentioned while discussing the 'b' values, it is also not easy to compare the rates of respiration for unit weight of the animal per hour. Therefore, only a rough comparison is possible, but

such a comparison is felt to be useful in order to find out the relative position of the present species among other species whose rates of respiration are known. In order to make the discussion brief and easier the comparison of the present results is confined to only isopods. Reinders (1933) reported that in Porcellio scaber the rate of respiration per gram wet weight of the animal per hour was 147.5 µl at 16°C. The rate in Asellus aquaticus is reported as varying from 505 to 863 µl at 10°C by Fox et al (1935). In Armadillidium pallasii it is 105 µl at 21°C (Muller, 1943); in Oniscus asellus it is 348 µl at 17°C (Edwards, 1946). In Ligia oceanica the rate varied from 179 to 400 µl at 25°C (Ellenby, 1951). In the same species Edney & Spencer (1955) has reported the rate as 192 µl at 22°C; in Armadillidium vulgare the rate is 202 µl at 22°C and in Oniscus asellus 214 µl at 22°C (Edney & Spencer loc. cit.). Eltringham (1965a) has reported 185.3 µl (converted into wet weight) at 25°C and 125.3 µl at 20°C in Limnoria spp. But he has been able to give only a single value in each temperature, and these values are only closer to the lowest range reported for Ligia oceanica by Ellenby (1951) and the single value reported for the same species by Edney & Spencer (1955).

In the present studies on Sphaeroma terebrans the rates obtained varied from 189.1 to 410.2 µl in 5 ‰ salinity (Table 4, page 33) and 242.8 to 1134.0 µl in 20 ‰ salinity (Table 6, page 36) at 28°C. Comparing the present values with those obtained for other isopods will show that the values obtained in 5 ‰ salinity compare well with the rates reported by Ellenby (1951) for Ligia oceanica. It will also be seen that the single values reported for Armadillidium vulgare, Ligia oceanica, Oniscus asellus, Porcellio scaber and Limnoria spp. also fall within this range. But the range in 20 ‰ salinity for S. terebrans is very high when compared with the values obtained for all the isopods mentioned above, except in the case of Asellus aquaticus. In the latter the lowest rate of 505 µl is far higher than the lowest value 242.8 µl in Sphaeroma terebrans in 20 ‰ salinity. But the highest value 863 ul is significantly lower than the value 1134.0 µl obtained in S. terebrans.

The high rates of respiration in Sphaeroma terebrans show that in this species apparently no adaptation to low oxygen supply has been evolved in conjunction with its wood-boring activity. The high rates also seem to confirm the conjunction that high energy expenditure is involved in the boring activity. Field observations have shown that there is more attack of Sphaeroma terebrans when the salinity is round about 20 ‰ compared to the period when the salinity is somewhere 5 ‰. Sphaeroma terebrans generally burrows timber in the intertidal region only. Their high rate of oxygen requirement seems to limit their distribution to this particular zone. Further, the high rate of oxygen requirement also seems to have put a limitation on the boring activity to the surface region of timber in the intertidal region where usually highly air saturated water is available.

(B) Oxygen consumption in relation to variations in salinity and body weight:-

The values of 'b' obtained for Sphaeroma terebrans acclimated in 20 ‰ salinity and transferred to salinities 0 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ are 0.1350, 0.7927, 0.7511, 0.9092, 0.3428, 0.6077, 0.7080 and 0.4094, respectively (figs. 16 and 17 and table 7, page 39). No work has been done on these lines by anyone in isopods to make any comparison. Eltringham's (1965a) work on Limnoria does not give any 'b' values. In the present experiments on Sphaeroma terebrans the values obtained show that in the different media the rate of oxygen consumption does not vary with the same power of body weight. In all the media tested the total oxygen consumption in the species increased with size, but the magnitude of increase in different media varied. It was minimum in 0 ‰ salinity and maximum in 10 ‰ salinity as evidenced by the 'b' values 0.1350 and 0.9092, in the respective media. It will further be found that in all the media, except in 0 ‰ salinity, the 'b' values were highly positive. Comparing the 'b' value in the acclimation medium of 20 ‰ salinity with the values of 'b' in other media (table 8, page 40), it is found that there is significant difference in 1 ‰ and 10 ‰ salinities. Comparisons between other values show significant differences existing between values in 0 ‰ and 1 ‰, 0 ‰ and 5 ‰, 0 ‰ and 10 ‰, 1 ‰ and 50 ‰, and 10 ‰ and 50 ‰ salinities.

The rate of oxygen consumption in µl/hr for animals of 15 mg, 30 mg, 45 mg and 60 mg weight groups was calculated from the 'b' value data presented in figs. 16 and 17. The details are given in table 11 (Page 51) and illustrated in figs. 28 and 29.

The fig. 28 illustrates the interrelationships of the rates of respiration of the 4 size groups of Sphaeroma terebrans in the different media. From the same it will be seen that the rate of respiration is maximum in the acclimation salinity of 20 ‰ in all the four size groups. In 45 mg and 60 mg size groups of animals, even though the rates of

TABLE 11

The rate of $O_2$ uptake in different salinities in animals of weight 15 mg, 30 mg, 45 mg and 60 mg under 140 mm Hg pressure of $O_2$ (values taken from figs. 16 and 17)

| Sl. No. | Body wt. mg. | $O_2$ uptake in µl/hr | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Salinities | | | | | | | |
| | | 0 ‰ | 1 ‰ | 5 ‰ | 10 ‰ | 20 ‰ | 30 ‰ | 40 ‰ | 50 ‰ |
| 1 | 15 | 6.457 | 3.715 | 3.508 | 3.548 | 10.23 | 5.559 | 5.370 | 5.559 |
| 2 | 30 | 7.161 | 6.457 | 5.957 | 6.607 | 13.03 | 8.610 | 8.810 | 7.413 |
| 3 | 45 | 7.586 | 8.810 | 7.943 | 9.441 | 14.96 | 10.84 | 11.61 | 8.710 |
| 4 | 60 | 7.943 | 11.220 | 10.00 | 12.300 | 16.60 | 13.03 | 14.45 | 9.772 |

FIG. 28

Illustrating the inter-relationship of the four size groups of *Sphaeroma terebrans* (15 mg, 30 mg, 45 mg & 60 mg) in their rate of $O_2$ consumption when exposed to different salinity media at 140 mm Hg pressure of $O_2$.

FIG. 29

Illustrating the trend of variation in the rate of $O_2$ consumption in the four size groups of *Sphaeroma terebrans* (15 mg, 30 mg, 45 mg & 60 mg) when exposed to different salinity media at 140 mm Hg pressure of $O_2$.

FIG.28

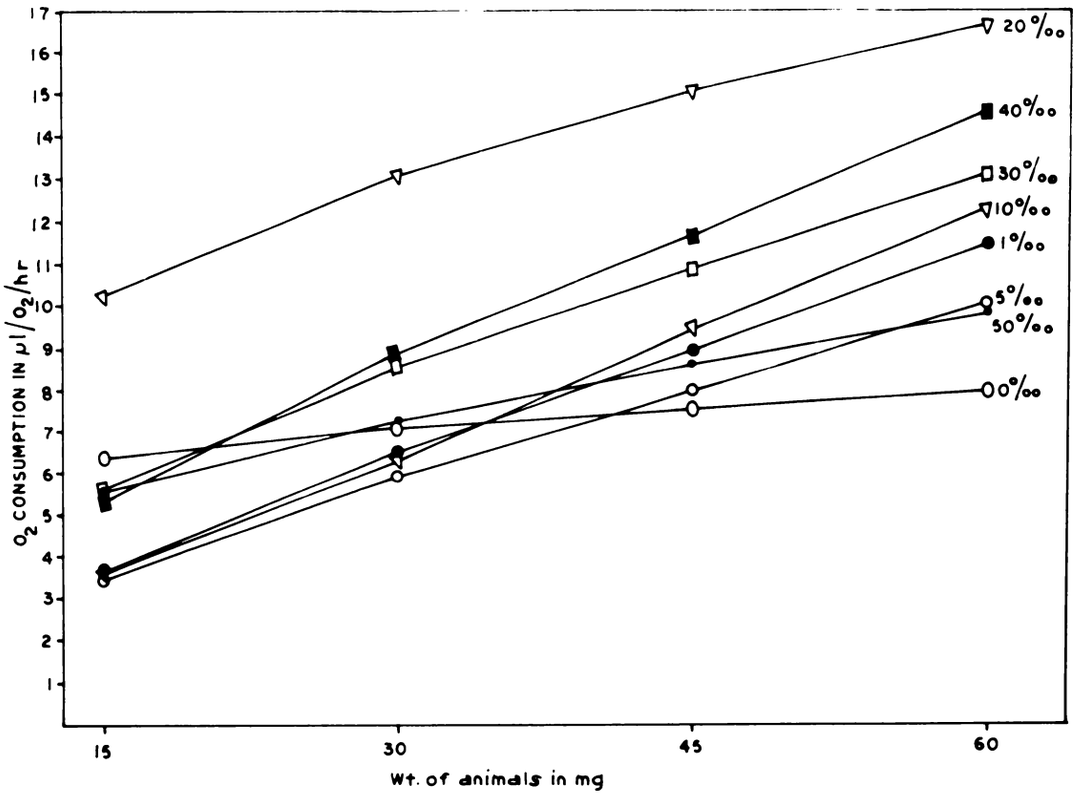
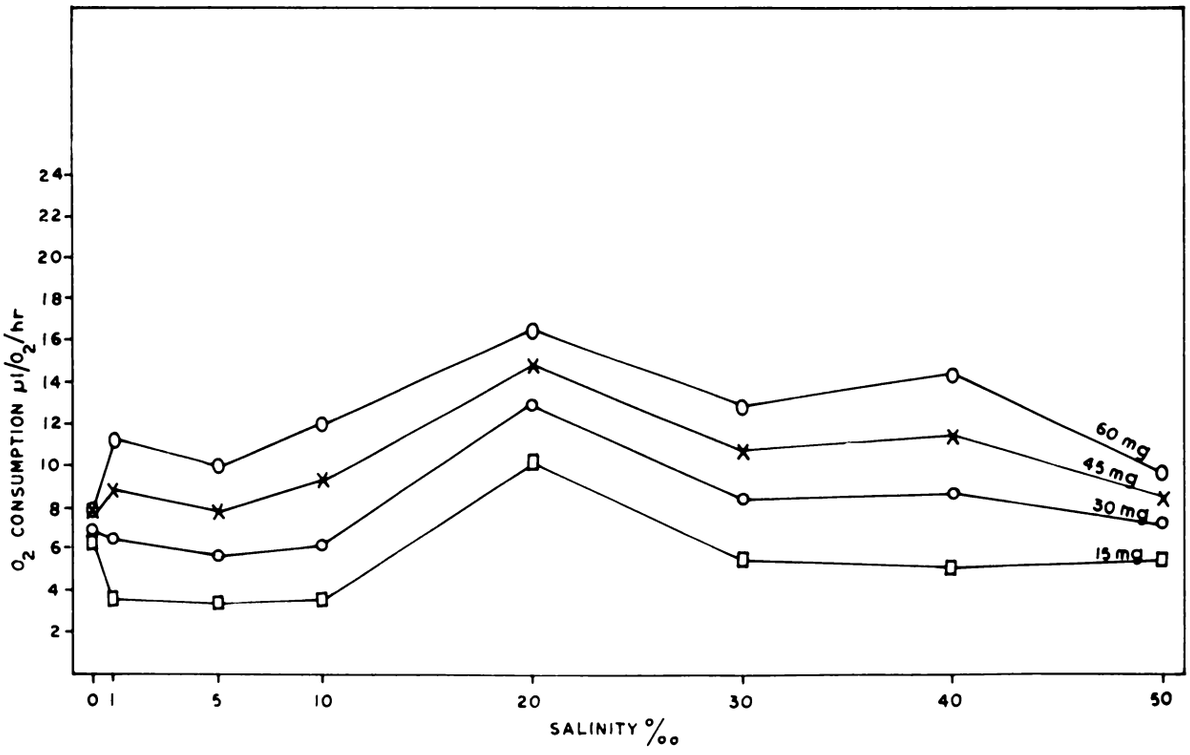

20‰
40‰
30‰
10‰
1‰
5‰
50‰
0‰
O2 CONSUMPTION IN µl/O2/hr
Wt. of animals in mg
15
30
45
60

FIG.29


60 mg
45 mg
30 mg
15 mg
O2 CONSUMPTION µl/O2/hr
SALINITY ‰
0 1
5
10
20
30
40
50

respiration vary in the different salinity media, they show almost the same pattern in all the salinities except 50 ‰. In 15 mg and 30 mg animals a definite pattern in the rate is noted only in salinities 1 ‰, 5 ‰ and 10 ‰. A scrutiny of the illustration in fig. 28 will further show that certain size groups of animals show theoritically similar rates of respiration in salinities widely different. Thus in 56 mg size animals the same rates are found in 5 ‰ and 50 ‰ salinities; in 40.5 mg animals in 5 ‰ and 0 ‰ salinities; in 38.5 mg animals in 1 ‰, 10 ‰ and 50 ‰ salinities; in 35 mg animals in 0 ‰, 1 ‰ and 10 ‰ salinities; in 28.5 mg animals in 0 ‰ and 50 ‰ salinities; in 22 mg animals in 0 ‰, 30 ‰ and 40 ‰ salinities; in 16.5 mg animals in 40 ‰ and 50 ‰ salinities and in 15 mg animals even though the lines do not cross each other giving exact values, the rate is very nearly the same in 1 ‰, 5 ‰ and 10 ‰ salinities and also in 30 ‰, 40 ‰ and 50 ‰ salinities.

The maximum rate of oxygen consumption in all the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg and 60 mg) in the acclimation medium of 20 ‰ salinity, suggests that in this medium all the size groups of animals are most actively engaged in all their life activities. A reduction in the rate in all the other media, therefore, appears to be due to the difficulty of the animals in adjusting to the sudden changes in media whereby the normal activities are restricted to a certain extent. Due to sudden changes in the environment some size groups of animals may show irregular responses and this irregularity sometimes results in showing identical values at certain points in widely different media in some size groups of animals.

The fig. 29 shows the trend of change in the rate of respiration in different salinity media for the various size groups of animals. It will be seen that, as already mentioned, the rate of respiration is maximum in 20 ‰ salinity medium in all the size groups and the rate increased proportionately as the weight of animals increased. But the rate showed a decrease in all the size groups of animals when they were transferred from 20 ‰ salinity acclimation medium to lower or higher test media. In the media of 10 ‰ and 30 ‰ salinities, the fall in the rate is almost

of the same pattern. In 40 ‰ medium the 15 mg animals do not show any appreciable difference in the rate compared to that in 30 ‰ medium. In 30 mg and 45 mg animals there is a slight increase in the rate in 40 ‰ medium, compared to that in 30 ‰ medium, and the maximum increase is found in 60 mg animals. In 50 ‰ salinity, while the 15 mg animals show only a slight increase in the rate of respiration, there is a proportionate fall in the rate in other size groups, the maximum fall being in 60 mg animals. In 5 ‰ salinity the rate is almost the same as in 10 ‰ medium for animals of 15 mg and 30 mg weight. In animals of 45 mg and 60 mg weight there is a decrease in the rate compared to that in 10 ‰ salinity. In 1 ‰ salinity all the size groups show a progressive increase to a slight extent in the rate of respiration. In 0 ‰ medium, in 15 mg and 30 mg animals, the rate increases and in 45 mg and 60 mg animals, there is a fall in the rate, the magnitude of this rise or fall is maximum in 15 mg and 60 mg animals.

From the above it is seen that (a) if an animal which is acclimated in 20 ‰ salinity is suddenly subjected to a lower or higher medium of salinity its rate of respiration gets reduced. This may be an indication that in such media the animal is unable to adapt immediately to carry out its usual life activities. (b) In the higher level 30 ‰ salinity seems to be the beginning of a critical level after which animals appear to show slight variations in their activities and from 40 ‰ salinity onwards the critical level is well demarcated in all the higher weight groups of animals, except in 15 mg group. (c) In the lower levels 5 ‰ salinity seems to be the beginning of a critical level below which the animals begin to show a slight increase in the rate of respiration, and in 1 ‰ and below the critical level is well defined in all the weight groups. (d) The lowest weight group, i.e. 15 mg animals, appears to be the least affected in all the media from 1 ‰ to 50 ‰ and so can be considered to be able to withstand adversities of environments. (e) The capacity to withstand adverse conditions appears to be proportionate to their size, i.e. as the size of the animals increased the capacity for tolerance decreased.

It is stated by several authors who have worked on Crustacea other than isopods, that when animals acclimated in a higher salinity media are transferred to lower salinity media, their rate of respiration increased, and according to them this increase is required to maintain the concentration of their body fluid. Experiments in such lines have been done on Carcinus maenas (Schlieper, 1929), Gammarus chevreuxi (Lowenstein, 1935), Ocypode albicans (Flemister & Flemister, 1951), Hemigrapsus oregonensis and H.nudus (Dehnel, 1960), Potamobius fluviatilis (Schwabe, 1933), Urphia spinifrons and Pagurus longicarpus (von Buddenbrock, 1948), Gammarus duebeni (Kinne, 1952), Artemia salina (Eliasen, 1952), Lepas anserifera and Sesarma plicatum (Madanmohan Rao and Pampapathi Rao, 1962). Kinne's (1952) experiments on G.duebeni showed that while animals are transferred from lower to higher salinity, oxygen intake showed a decrease. Lofts (1956) showed that Palaemonetes varians living in 1.4 ‰ average salinity had the minimum rate in 6 ‰ salinity and in Astacus astacus the rate decreased when transferred from fresh water to 15 ‰ sea water (Krogh, 1939).

But the above view that the increased respiration reflected the additional energy required for osmoregulation has been more recently questioned on the grounds that the extra energy requirements are very small to account for the respiratory differences as noted in Eriocheir (Potts, 1954), in Palaemonetes varians (Lofts, 1956), in Pachygrapsus (Gross, 1957), in Hemigrapsus oregonensis and H.nudus (Dehnel, 1960). Potts & Parry, (1964) in their review have also come to the same view. Further, Croghan (1961) has pointed out that if the ion exchange during osmoregulation is via an energy rich bond, the energy required will depend upon the rate at which the solute is transported and not upon the relative concentration of the internal and external media.

Some other authors also have noted the increase in the rates of oxygen consumption during transfer from a higher to lower salinity media, but they do not consider the increase as specially for osmoregulative activity alone. Gross (1957) maintains that the increase in the rate of

oxygen consumption is due to the struggle of the animal to escape from that medium. The studies by Gopalakrishnan (1953) on Madras ponacids by keeping the animals held tight in glass jackets show that the rise in the oxygen consumption in diluted medium is not due to the muscular activity of the animal. The view of Dehnel (1960) is also that the increased rate in low salinity does not result from increased muscular activity.

The opposite view that the rate of respiration decreased when animals from higher salinity media are transferred to low salinity media has been reported by a few authors. Krogs (1929a & 1929b) observed a decrease in the oxygen consumption in Balanus balanoides and B.crenatus in reduced salinities. von Buddenbrock (1948) has reported that in stenohaline Maja verrucosa the rate decreases in dilute media. Similar observations have been made by Prasada Rao (1965) in Balanus amphitrite communis and B.tintinnabulum tintinnabulum.

While all the above studies have shown either a rise or fall in the rate of oxygen consumption, Krogh (1939) has reported the same rate in Eriocheir sinensis in fresh water, in 15 ‰ sea water and 32 ‰ sea water. In Artemia salina no significant difference in the rate was found in media from 35 ‰ to 140 ‰ salinity (Gilchrist, 1956). Eltringham (1965a) in his studies on isopod, Limnoria did not come across any correlation between the respiratory rate and the concentration of the medium.

From the above it will be seen that when animals are transferred from higher to lower concentration media an increase in the rate of oxygen consumption is seen by a large number of workers and a decrease in the rate is observed by a smaller number of authors. At the same time a decrease in the rate is noted by a still smaller number of workers when the animal is transferred from lower to higher media. A very few workers did not find any appreciable difference in the rate when media are changed. Here, on the other hand, when Sphaeroma terebrans are transferred from lower to higher, or higher to lower salinity concentrations the rate of oxygen

uptake is only on the decrease. From this it appears that no hard and fast rule can be formulated in determining the rate of oxygen uptake of a crustacean in salinity media of different levels.

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(C) Oxygen consumption in relation to oxygen concentration, salinity variation and body weight:-

The experiments to determine the rate of respiration in Sphaeroma terebrans acclimated in 20 ‰ salinity, in different salinity media were continued to find out the rate of oxygen consumption under falling oxygen tension and also to determine the lethal level of oxygen for the species.

Observations on the 'b' values:-

The values of 'b' under 140, 120, 100, 80 and 60 mm Hg pressure of oxygen in the different salinity media were calculated using the method of least squares and are presented in figs. 18-25. It will be seen from the same that in all the media under the various partial pressures of oxygen the total oxygen consumption in the species increased with the increase in body weight. But the rate of oxygen consumption under the above conditions did not vary with the same power of body weight. The 'b' values obtained in 1 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ salinities are the same under 140 and 120 mm Hg pressure of oxygen. In 5 ‰ salinity the same value was found in 140, 120 and also in 100 mm Hg pressure. But in 0 ‰ salinity the value of 'b' showed a gradual decrease in 120 and 100 mm Hg pressure. Under 100, 80 and 60 mm Hg pressure in media of salinities 1 ‰, 5 ‰, 30 ‰ and 40 ‰ the value of 'b' increased as the oxygen concentration decreased. In 10 ‰ and 20 ‰ salinities under 100 mm Hg pressure the 'b' values showed a decrease and then increased in 80 (except in 10 ‰ salinity) and 60 mm Hg pressure and in 50 ‰ salinity even though the 'b' value increased under 100 and 80 mm Hg pressure, it decreased in 60 mm Hg pressure.

The 'b' values obtained in the different media under different oxygen pressures and their standard errors are presented in table 12 (Page 58).

The difference between the 'b' values obtained in the same medium under different pressures were statistically analysed using the 'Student's' 't' and the results are presented in table 13 (Page 59). From the same it will be seen that, except in three instances under 40 ‰ salinity, the

## TABLE 12

**Showing regression coefficients and their standard errors obtained under different $O_2$ pressures in different salinity for Sphaeroma terebrans.**

| Sl. No. | Salinity ‰ | | Partial pressure of oxygen in mm Hg. | | | | |
|---|---|---|---|---|---|---|---|
| | | | 60 | 80 | 100 | 120 | 140 |
| | | b | | | 0.1090 | 0.1126 | 0.1350 |
| 1 | 0 | n | — | — | 15 | 16 | 16 |
| | | $S_b$ | | | 0.2327 | 0.1450 | 0.1368 |
| | | b | 1.1132 | 1.0272 | 0.8676 | 0.7927 | 0.7927 |
| 2 | 1 | n | 22 | 22 | 22 | 22 | 22 |
| | | $S_b$ | 0.1321 | 0.1100 | 0.1021 | 0.1003 | 0.1003 |
| | | b | 1.0699 | 0.9264 | 0.7511 | 0.7511 | 0.7511 |
| 3 | 5 | n | 18 | 18 | 18 | 18 | 18 |
| | | $S_b$ | 0.1596 | 0.1289 | 0.1107 | 0.1107 | 0.1107 |
| | | b | 0.9357 | 0.8787 | 0.9042 | 0.9092 | 0.9092 |
| 4 | 10 | n | 21 | 21 | 21 | 21 | 21 |
| | | $S_b$ | 0.1121 | 0.1115 | 0.1095 | 0.1091 | 0.1091 |
| | | b | 0.5055 | 0.3629 | 0.3396 | 0.3428 | 0.3428 |
| 5 | 20 | n | 16 | 18 | 18 | 18 | 18 |
| | | $S_b$ | 0.1959 | 0.1457 | 0.1016 | 0.1009 | 0.1009 |
| | | b | 0.7048 | 0.6971 | 0.6407 | 0.6077 | 0.6077 |
| 6 | 30 | n | 19 | 19 | 19 | 19 | 19 |
| | | $S_b$ | 0.1359 | 0.1279 | 0.1126 | 0.1079 | 0.1079 |
| | | b | 0.9506 | 0.8165 | 0.7244 | 0.7080 | 0.7080 |
| 7 | 40 | n | 22 | 22 | 22 | 22 | 22 |
| | | $S_b$ | 0.0860 | 0.0808 | 0.0755 | 0.0734 | 0.0734 |
| | | b | 0.2835 | 0.5550 | 0.4298 | 0.4094 | 0.4094 |
| 8 | 50 | n | 17 | 17 | 17 | 17 | 17 |
| | | $S_b$ | 0.1342 | 0.1394 | 0.1019 | 0.0857 | 0.0857 |

## TABLE 13

**Showing the significance of differences between the regression coefficients obtained under different partial pressures of oxygen in the same medium.**

| | | Comparing partial pressure of $O_2$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sl. No. | Media | 140 & 120 | 140 & 100 | 140 & 80 | 140 & 60 | 120 & 100 | 120 & 80 | 120 & 60 | 100 & 80 | 100 & 60 | 80 & 60 |
| 1 | 0 % | N.S.* | N.S. | — | — | N.S. | — | — | — | — | — |
| 2 | 1 % | — | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| 3 | 5 % | — | — | N.S. | N.S. | — | N.S. | N.S. | N.S. | N.S. | N.S. |
| 4 | 10 % | — | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| 5 | 20 % | — | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| 6 | 30 % | — | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| 7 | 40 % | — | N.S. | N.S. | 0.02 to 0.05 | N.S. | N.S. | 0.02 to 0.05 | N.S. | 0.02 to 0.05 | N.S. |
| 8 | 50 % | — | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

* N.S. Not significant.

differences between them are not significant and this shows that in general under the same medium the same relationship with regard to the rate of oxygen consumption in the different size groups of animals is maintained under the varying oxygen concentration.

The 'b' values calculated under different pressures in different media were also compared and the data are presented in table 14 (Page 61). From the same it will be seen that in about 52 % cases the differences between the values are not significant, nearly 17 % have their probabilities between 0.01 and 0.05 and in the remaining 31 % the values are significant.

Rates of respiration under different oxygen pressures and salinity:-

Figs. 30-37 illustrate the rates of respiration under 140, 120, 100, 80 and 60 mm Hg pressures for 15 mg, 30 mg, 45 mg and 60 mg size groups of animals in the media of salinities 0 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰. From the same it will be seen that for each size group, 15 mg, 30 mg, 45 mg and 60 mg animals, in all the test media, the rate of respiration remained the same under 140 and 120 mm Hg pressures of oxygen, except in 0 ‰ salinity. In 0 ‰ salinity 30 mg, 45 mg and 60 mg animals showed a gradual fall in the rate as the concentration of oxygen decreased to 120 and 100 mm Hg pressure. In this medium 15 mg animals showed a slight increase in the rate in 120 mm Hg pressure before registering a fall in 100 mm Hg pressure. In 0 ‰ salinity the rates could be obtained only up to 100 mm Hg pressure and after this the rates fell abruptly and animals died. When the oxygen concentration decreased to 100, 80 and 60 mm Hg pressure a gradual fall in the rates was observed in 20 ‰, 30 ‰, 40 ‰ and 50 ‰ salinities in all the size groups, and this was more perceptible in 45 and 60 mg animals. In lower salinities (1 ‰, 5 ‰ and 10 ‰) the rate of change in respiration in 100, 80 and 60 mm Hg pressure was somewhat different from what was observed in 20, 30, 40 and 50 ‰ salinities. In 5 ‰ and 10 ‰ salinities under 100 mm Hg pressure almost the same rates as that in 140 and 120 mm Hg pressure were observed and in 80 and 60 mm Hg pressure there was a gradual fall in the rate. In 1 ‰ salinity in 15 mg animals there was a gradual fall from

## TABLE 14

**Showing the significance of differences between the regression coefficients obtained in different media under different partial pressure of oxygen.**

| Sl. No. | Comparing media % | 140 mm Hg | 120 mm Hg | 100 mm Hg | 80 mm Hg | 60 mm Hg |
|---|---|---|---|---|---|---|
| | | Probability | | | | |
| 1 | 0 and 1 | < 0.01 | < 0.01 | < 0.01 | — | — |
| 2 | 0 and 5 | < 0.01 | < 0.01 | 0.01 to 0.02 | — | — |
| 3 | 0 and 10 | < 0.01 | < 0.01 | < 0.01 | — | — |
| 4 | 0 and 20 | N.S. * | 0.02 to 0.05 | N.S. | — | — |
| 5 | 0 and 30 | 0.01 to 0.02 | 0.01 to 0.05 | 0.02 to 0.05 | — | — |
| 6 | 0 and 40 | < 0.01 | < 0.01 | 0.01 to 0.02 | — | — |
| 7 | 0 and 50 | N.S. | 0.01 to 0.05 | N.S. | — | — |
| 8 | 1 and 5 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 9 | 1 and 10 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 10 | 1 and 20 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.01 to 0.02 |
| 11 | 1 and 30 | N.S. | N.S. | N.S. | 0.05 | 0.02 to 0.05 |
| 12 | 1 and 40 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 13 | 1 and 50 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| 14 | 5 and 10 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 15 | 5 and 20 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.02 to 0.05 |
| 16 | 5 and 30 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 17 | 5 and 40 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 18 | 5 and 50 | 0.01 to 0.05 | 0.01 to 0.05 | 0.02 to 0.05 | 0.05 | < 0.01 |
| 19 | 10 and 20 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | N.S. |
| 20 | 10 and 30 | 0.01 to 0.05 | 0.01 to 0.05 | N.S. | N.S. | N.S. |
| 21 | 10 and 40 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 22 | 10 and 50 | < 0.01 | < 0.01 | < 0.01 | N.S. | < 0.01 |
| 23 | 20 and 30 | N.S. | N.S. | 0.02 to 0.05 | N.S. | N.S. |
| 24 | 20 and 40 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | N.S. |
| 25 | 20 and 50 | N.S. | N.S. | N.S. | N.S. | N.S. |
| 26 | 30 and 40 | N.S. | N.S. | N.S. | N.S. | 0.01 to 0.02 |
| 27 | 30 and 50 | N.S. | N.S. | N.S. | N.S. | 0.02 to 0.05 |
| 28 | 40 and 50 | < 0.01 | < 0.01 | < 0.01 | N.S. | < 0.01 |

* N.S. Not significant.

FIG. 30

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 0 ‰ salinity medium.

FIG. 31

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 1 ‰ salinity medium.

FIG. 32

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 5 ‰ salinity medium.

FIG. 33

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 10 ‰ salinity medium.

FIG.30

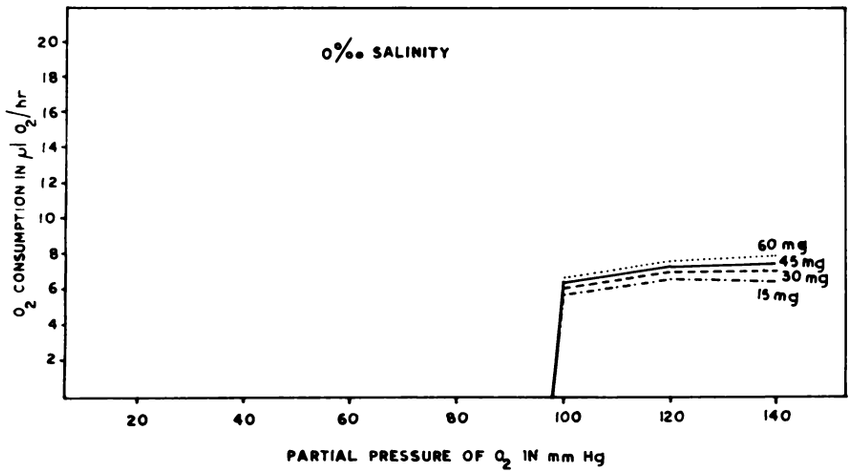



FIG.31

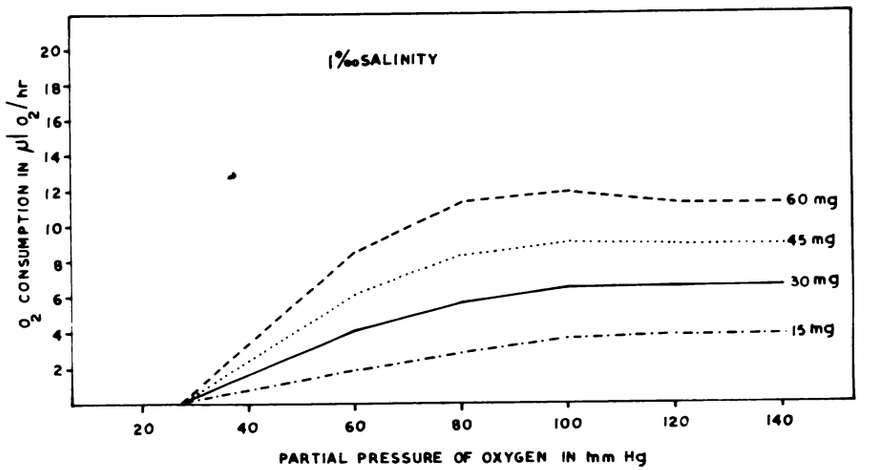



FIG.32

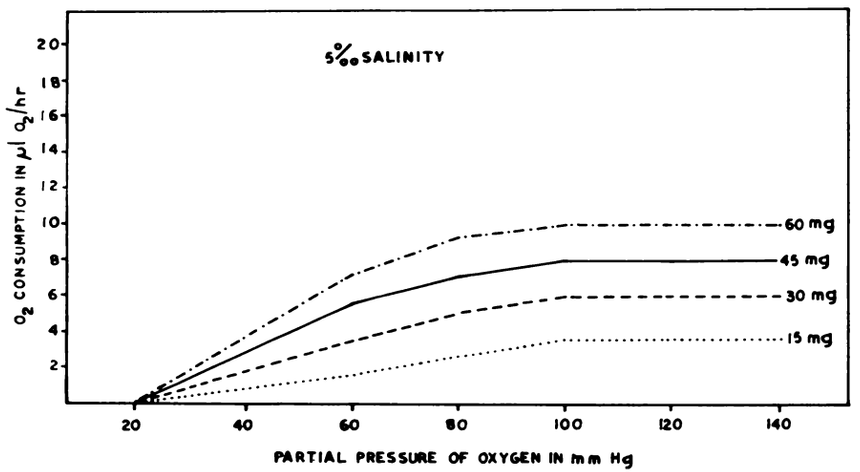



FIG.33

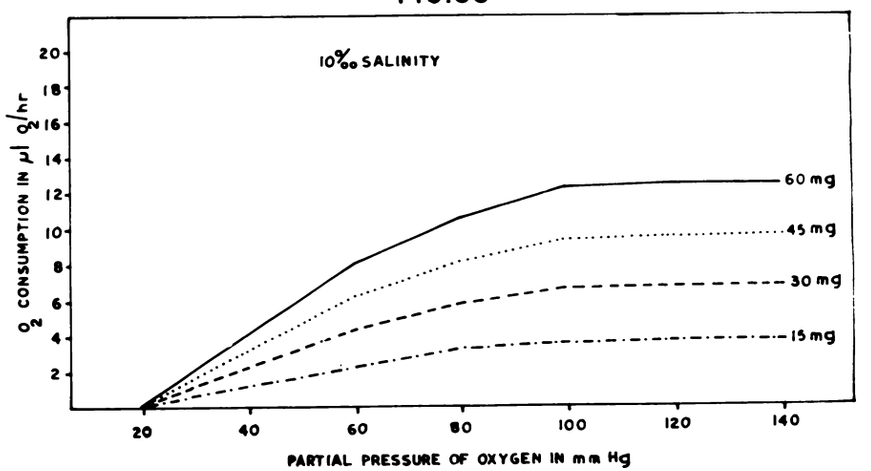


FIG. 34

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 20 ‰ salinity medium.

FIG. 35

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 30 ‰ salinity medium.

FIG. 36

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 40 ‰ salinity medium.

FIG. 37

Illustrating the trend of change in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) at various $O_2$ concentrations in 50 ‰ salinity medium.

FIG.34

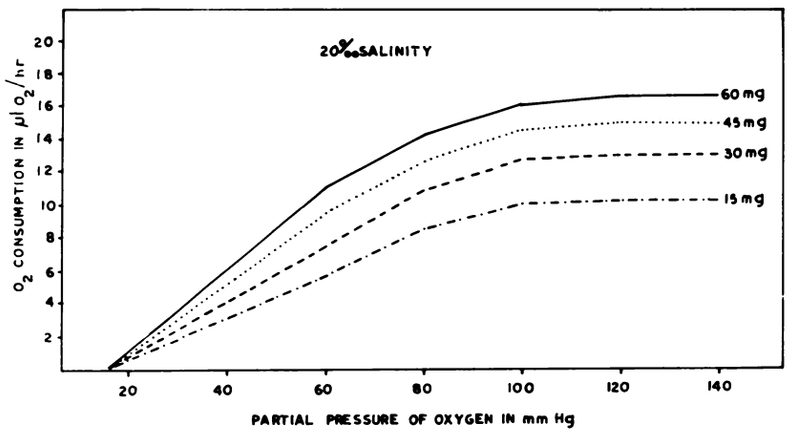



FIG.35

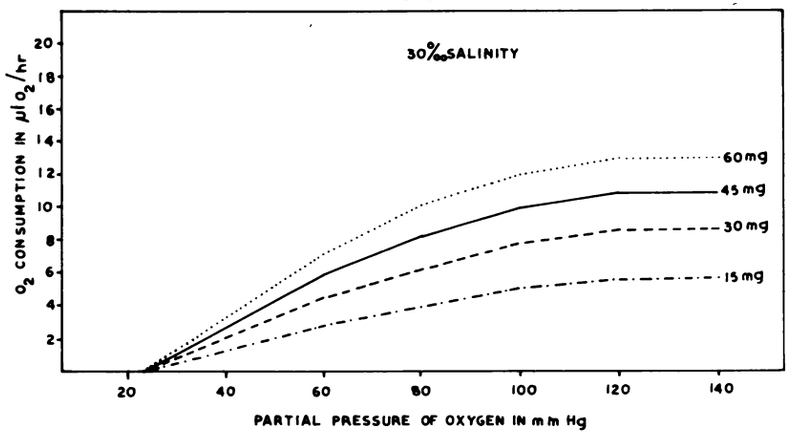



FIG.36

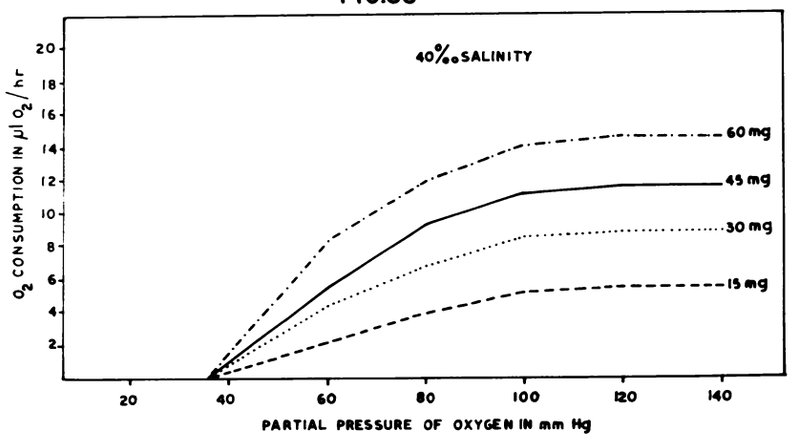
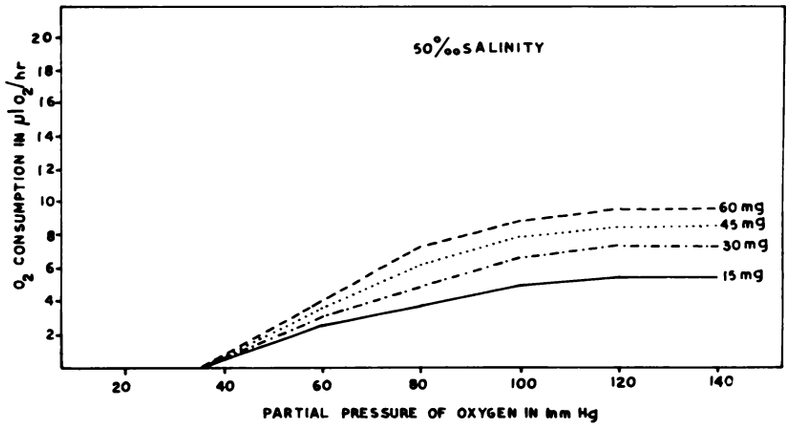



FIG.37



100 mm Hg pressure downwards. In 30 mm Hg animals the same rates were maintained up to 100 mm Hg and then there was a gradual fall. In 45 mg animals there was an increase in the rate after 120 mm Hg pressure when it reached 100 mm Hg pressure and from there the rate fell gradually. In 60 mg animals also there was a rise in the rate after 120 to 100 mm Hg pressure and from there the rate decreased when it reached 80 mm Hg pressure, but this rate was higher than that obtained in 140 and 120 mm Hg pressure. From 80 mm Hg pressure there was a fall up to 60 mm Hg and below.

In general, the zone between 140 and 120 mm Hg pressure where the rate of respiration is the same for all size groups of animals in all salinities except in 0 ‰ can be called as the non-dependent zone. In a few media and in certain size groups this non-dependent zone extends even up to 100 mm Hg pressure. Below this zone the rate of oxygen consumption decreases and so this zone can be called as the dependent zone. The pressure 120 and in some 100 mm Hg at which the rate begins to decrease can be called as the critical level of oxygen concentration because below this level the decrease in the oxygen concentration gradually results in a fall in the rate of oxygen consumption leading to the ultimate death of the animal. In 1 ‰ salinity medium the 45 and 60 mg animals showing the slight increase in the rate of respiration after 120 mm Hg pressure before registering a fall in the rate may be due to the struggle of the animals to adapt to the falling oxygen concentration.

Trend in the oxygen consumption in non-dependable and dependable zones:-

The non-dependable level of oxygen has been found to be 140 to 120 mm Hg pressure in some weight groups and media and 140 to 100 mm Hg pressure in some others. The rate of oxygen consumption in different pressures of oxygen in the different media of salinities was calculated. The rate under 140 mm Hg pressure of all the weight groups acclimated i 20 ‰ salinity and suddenly transferred to higher and lower concentrati have already been discussed in page 52 and illustrated in fig. 29. Her figs. 38-41 give the trend in 120, 100, 80 and 60 mm Hg pressures of o It is found that the trend is almost the same in all the salinity medi

FIG. 38

Illustrating the trend of variations in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) when exposed to different salinity media at 120 mm Hg pressure of $O_2$.

FIG. 39

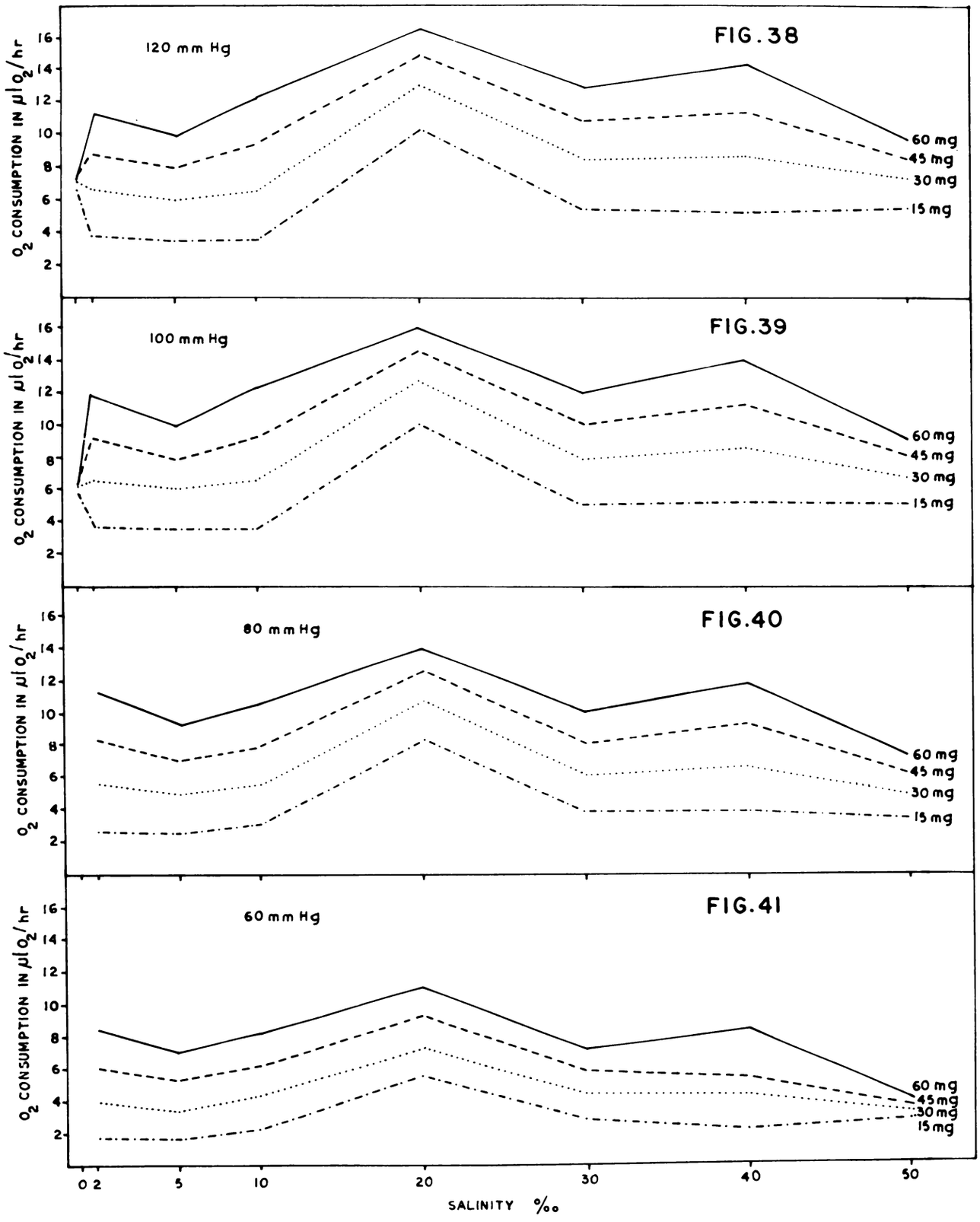
Illustrating the trend of variations in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) when exposed to different salinity media at 100 mm Hg pressure of $O_2$.

FIG. 40

Illustrating the trend of variations in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) when exposed to different salinity media at 80 mm Hg pressure of $O_2$.

FIG. 41

Illustrating the trend of variations in the rate of $O_2$ consumption in the four size groups of Sphaeroma terebrans (15 mg, 30 mg, 45 mg & 60 mg) when exposed to different salinity media at 60 mm Hg pressure of $O_2$.


120 mm Hg
FIG. 38
100 mm Hg
FIG. 39
80 mm Hg
FIG. 40
60 mm Hg
FIG. 41
O2 CONSUMPTION IN µl O2/hr
60 mg
45 mg
30 mg
15 mg
0 2
5
10
20
30
40
50
SALINITY ‰

under different pressures, the maximum rate is in the acclimation medium and when the animals are transferred to higher or lower salinity media the rate of oxygen consumption is lowered.

Inter-relationship in the rate of respiration under different oxygen concentrations:-

Figs. 42-49 show that in general, the rate of respiration is at the maximum in 140 and 120 mm Hg pressure of oxygen for all the four size groups of animals, the larger animals showing higher rates of respiration. The rate under 100 mm Hg is not very much different from that in the above two oxygen concentrations and in 5 ‰ salinity equal rates are found. The rate in 80 and 60 mm Hg pressure is progressively low. The difference between the rates under 80 and 60 mm Hg pressure is much more than that found under 100 and 80 mm Hg pressure. This is found to be more pronounced in larger animals. In 1 ‰ salinity 45 mg animals showed higher rate of consumption in 100 mm Hg pressure than that in 140 mm Hg pressure. In the same medium under 100 and 80 mm Hg pressures 60 mg animals also showed higher rates than that found under 140 mm Hg pressure. From this it appears that higher size groups of animals struggle more as the concentration of oxygen goes down and this results in higher rates of respiration.

Lethal level of oxygen in different salinity media:-

Here, by lethal level is meant the level of oxygen concentration in the medium at the time of the death of the animal. The volume of oxygen in the experimental medium at the time of death of each animal in all the series of experiments was noted and the values were statistically analysed and are presented in table 10 (Page 44) and fig. 26. It was found that there is a linear relationship between the different size groups in all the media. The 'b' values calculated in the different media of salinities 0 ‰, 1 ‰, 5 ‰, 10 ‰, 20 ‰, 30 ‰, 40 ‰ and 50 ‰ are -0.0338, -0.00917, -0.000327, -0.00368, +0.00116, -0.00448, -0.00585 and -0.00445, respectively. The 'b' values were tested for their significance using 'Student's' 't' and it was found that each value is not significantly different from zero which shows that the lethal level of oxygen for

FIG. 42

Illustrating the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 50 ‰ salinity medium at different $O_2$ pressures.

FIG. 43

Illustrating the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 40 ‰ salinity medium at different $O_2$ pressures.

FIG. 44

Illustrating the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 30 ‰ salinity medium at different $O_2$ pressures.

FIG. 45

Illustrating the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 20 ‰ salinity medium at different $O_2$ pressures.

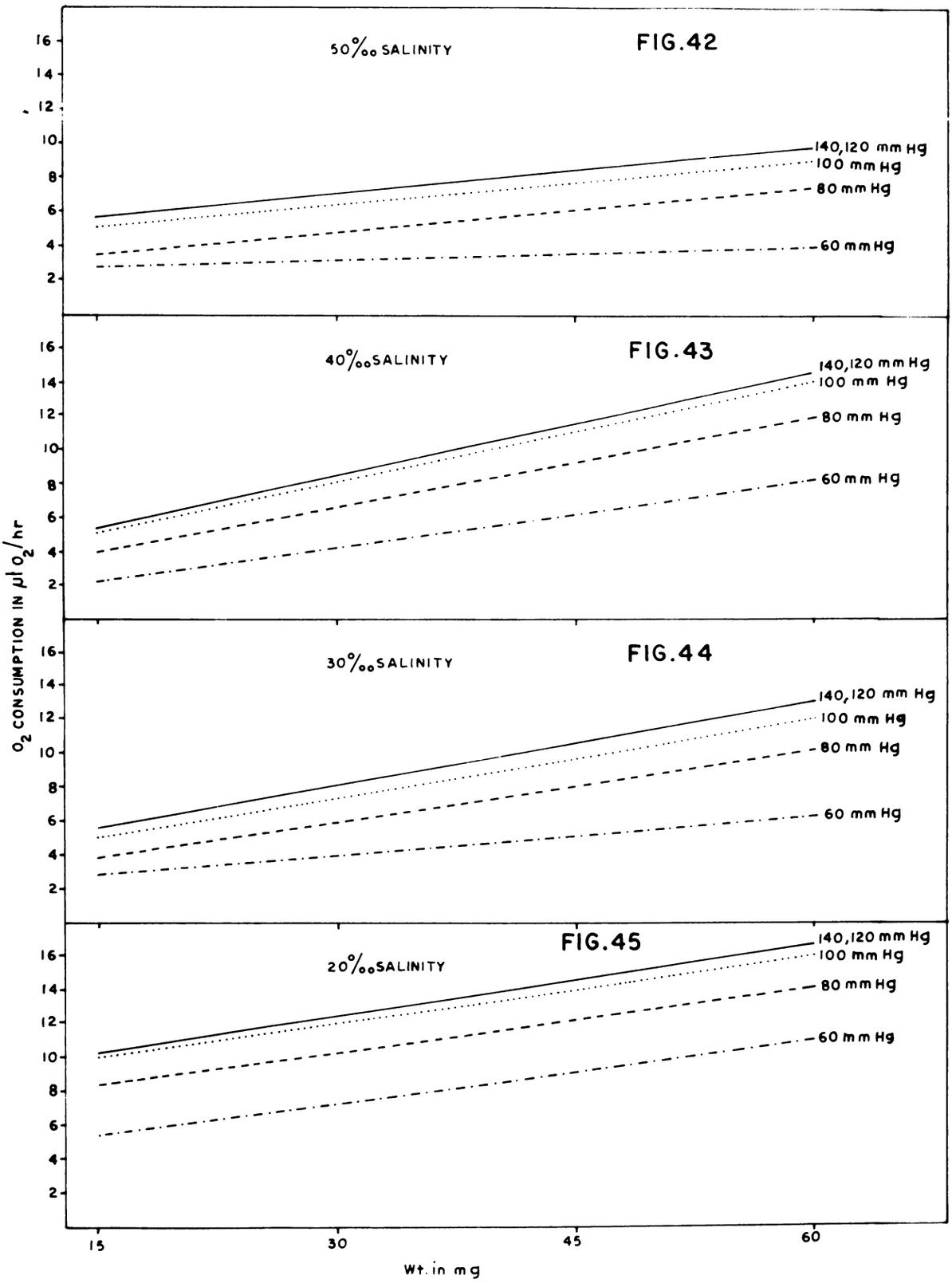

50‰ SALINITY
FIG.42
140,120 mm Hg
100 mm Hg
80 mm Hg
60 mm Hg
40‰ SALINITY
FIG.43
140,120 mm Hg
100 mm Hg
80 mm Hg
60 mm Hg
30‰ SALINITY
FIG.44
140,120 mm Hg
100 mm Hg
80 mm Hg
60 mm Hg
20‰ SALINITY
FIG.45
140,120 mm Hg
100 mm Hg
80 mm Hg
60 mm Hg
O2 CONSUMPTION IN µl O2/hr
Wt. in mg
15
30
45
60

FIG. 46

Illustration of the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 10 ‰ salinity medium at different $O_2$ pressures.

FIG. 47

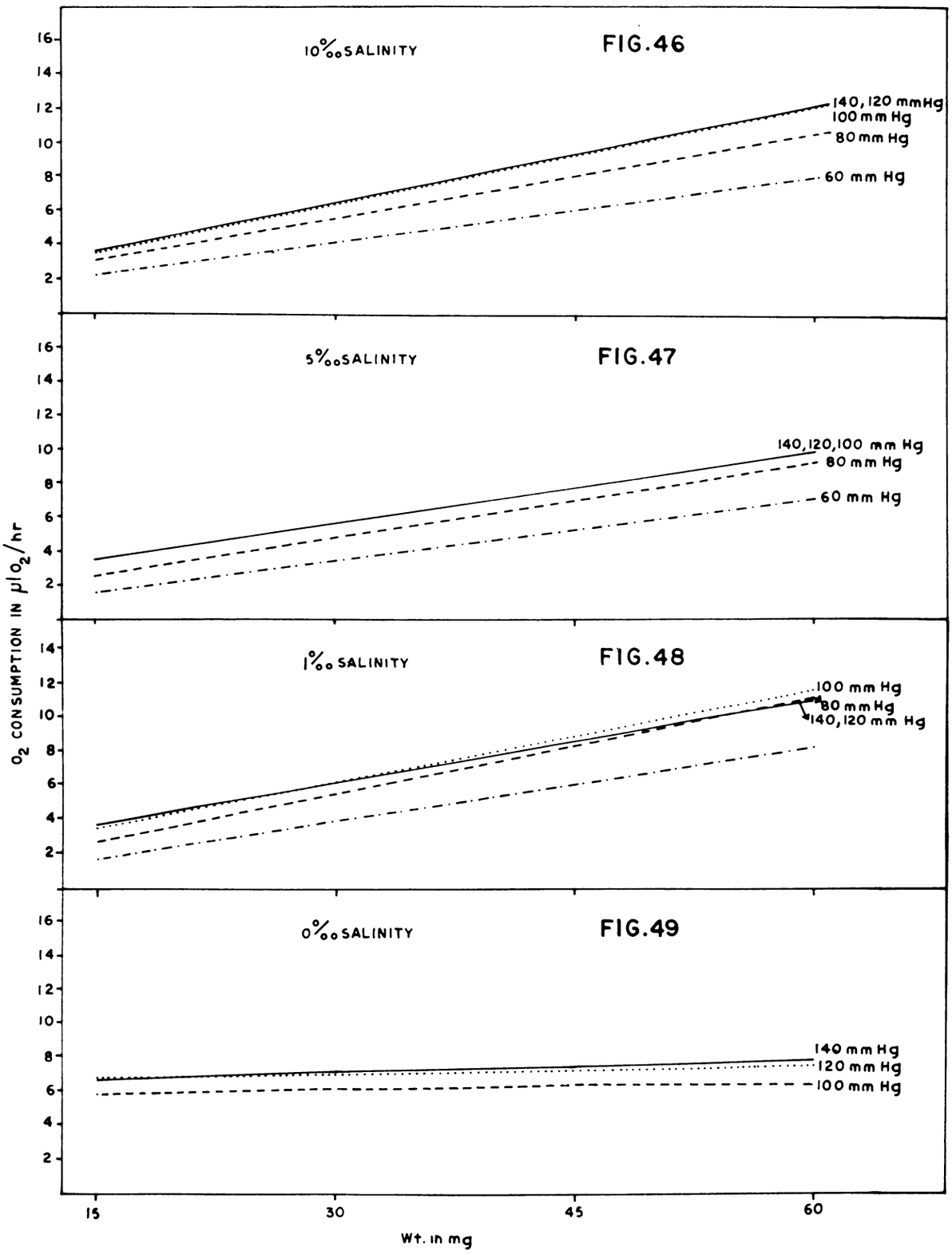
Illustration of the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 5 ‰ salinity medium at different $O_2$ pressures.

FIG. 48

Illustration of the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 1 ‰ salinity medium at different $O_2$ pressures.

FIG. 49

Illustration of the trend of change in the rate of respiration in Sphaeroma terebrans of weight 15 mg, 30 mg, 45 mg & 60 mg in 0 ‰ salinity medium at different $O_2$ pressures.


10‰ SALINITY
FIG. 46
140, 120 mmHg
100 mm Hg
80 mm Hg
60 mm Hg
5‰ SALINITY
FIG. 47
140, 120, 100 mm Hg
80 mm Hg
60 mm Hg
1‰ SALINITY
FIG. 48
100 mm Hg
80 mm Hg
140, 120 mm Hg
0‰ SALINITY
FIG. 49
140 mm Hg
120 mm Hg
100 mm Hg
O2 CONSUMPTION IN μl O2/hr
Wt. in mg
15
30
45
60

different weight groups of animals in a particular medium does not vary significantly.

The lethal level of oxygen for the species in different media was calculated and is given in the following table and also in figs. 27 and 30-37.

| Salinity media ‰ | | Level of oxygen at the time of death of the animal. ml/L | | Oxygen concentration expressed in mm Hg pressure. |
|---|---|---|---|---|
| 0 | - | 3.46 | - | 97.98 |
| 1 | - | 0.97 | - | 27.57 |
| 5 | - | 0.62 | - | 17.64 |
| 10 | - | 0.66 | - | 19.70 |
| 20 | - | 0.55 | - | 17.43 |
| 30 | - | 0.67 | - | 22.62 |
| 40 | - | 1.02 | - | 33.64 |
| 50 | - | 0.91 | - | 35.10 |

The data show that the lethal level of oxygen is not significantly different in salinities from 5 ‰ to 30 ‰ in any of the weight groups of the animals. In salinities above 30 ‰ and also below 5 ‰ the level shows significant increase. In salinities 40 ‰ and 50 ‰ the increase can be expected because animals will normally find it difficult to adjust to such media, because in the natural environment salinity does not reach such levels in the Cochin harbour area. In 1 ‰ salinity also the animals cannot adjust very much and so the lethal level of oxygen increases. In 0 ‰ salinity the lethal level is very high because the medium itself is not suitable for the animal to live and so the death is quick.

No work on isopods regarding their lethal levels of oxygen in the medium has been done so far, and so it is not possible to make any comparison. Subrahmanyam (1962) has conducted experiments on a marine prawn Penaeus

*indicus* to find out the relationship between the weight of the animal and the lethal level of oxygen concentration. According to him in *P.indicus* the lethal level of oxygen increases with the weight of the animal and the values varied from 1.49 ml/L to 3.80 ml/L for animals of weight ranging from 0.60 gm to 10.0 gm and he got an exponent value of 0.345. But in the present experiments the lethal level does not change with the weight of the animal.

A scrutiny of the works referred to in the introduction part of the chapter will enable to group the different species of crustaceans, whose rates of respiration under varying oxygen concentrations are known, broadly into two. The first group is formed of these species whose rate of respiration is directly related to the concentration of oxygen in the medium below air saturation level and they are termed as 'conformers' (Lockwood, 1967). Some of the examples are *Eriocheir sinensis*, *Asellus aquaticus*, *Homarus vulgaris*, *Pseudosquilla ciliata*, *Gammarus lineatus*, *Cambarus bartoni* and *Procambarus clarkii*. The second group is formed of those species whose rate of respiration is independent of the oxygen concentration until a certain critical oxygen tension or critical pressure is reached and below this critical level the rate is related to the oxygen concentration. A few examples are *Scyllarides latus*, *Carcinus maenas*, *Cambarus viridis*, *Pugettia producta*, *Calanus finmarchicus*, *Uca pugnax*, *U.pugilator*, *Nurytium limosum*, *Orconectes virilis*, *Balanus amphitrite amphitrite* and *B.tintinnabulum tintinnabulum*.

A comparison of the pattern of the rates of respiration in these two groups with the observations made on *Sphaeroma terebrans* will show that the present species comes under the second group. It seems that in many cases the reason for the two types of respiratory patterns can be traced back to the natural environments of the animals. The animals that come under the first group generally live in environments in which a fall in the oxygen concentration is very unusual. Whereas in the habitat of the second group of animals they usually experience temporary depletion in the oxygen concentration.

In the second group of animals the critical pressure of oxygen varies from species to species, probably depending upon the habitat conditions of the animal. Thus the critical level in Scyllarides latus and Carcinus maenas is at 2.5 ml$O_2$/L (Homme, 1910); in Pugettia producta, 50 - 70 mm Hg pressure (Weymouth et al, 1944); in Calanus finmarchicus, about 50 % air saturation level (Marshal & Orr, 1958); in Uca pugnax, U.pugilator and Eurytium limosum, less than 3 % that for air (Teal, 1959); in Orconectus virilis, 25 % air saturation level (Hiestand, 1931); in Balanus amphitrite amphitrite and B.tintinnabulum tintinnabulum, at 2.5 and 3.5 ml$O_2$/L, respectively (Prasada Rao & Ganapati, 1968).

A comparison of the above cited critical values with that obtained in the present studies in acclimation salinity of 20 ‰ will show that the value of 100 mm Hg pressure is somewhat high. Sphaeroma terebrans is usually found in the upper layers of water in the Cochin harbour area where comparatively high concentration of oxygen is usually observed and therefore the chances for the animal to experience extremely low oxygen concentrations under normal conditions are rather remote. This probably explains for the comparatively high critical level of oxygen observed in the species. In the higher and lower test media and sometimes in certain size groups the critical level is found to vary. This is evidently due to the influence of the salinity of the medium and also the size of the animal.

## SUMMARY

Sphaeroma terebrans Bate, one of the most destructive wood-boring isopod crustacean occurring in the Cochin harbour region was taken up for investigations on its habitat, breeding, attack on timber, salinity tolerance and respiration. The respiration of the animal under different stresses was noted using an instrument fabricated in the laboratory.

Of the various hydrographic conditions of the Cochin harbour region studied, salinity is found to be the most fluctuating factor and the variations are largely influenced by the seasonal rain fall from one side and the tidal currents on the other.

In spite of the great fluctuations in salinity Sphaeroma terebrans occurs throughout the year in the Cochin harbour region, though their number varies in different months.

Exposure tests show that Sphaeroma terebrans can remain for about 20 to 24 hours outside water in a damp atmosphere.

Field studies in the Cochin harbour region reveal that the species breeds throughout the year and animals of 5 mm length have been found to carry eggs in their breed-pouch. A sudden rise in breeding starts at a time when there is an abrupt fall in the value of salinity due to heavy rain fall. Intense breeding and the consequent overcrowding can be considered as factors influencing the migration of the species. However, the high rate of breeding in the monsoon period does not appear to help the species to find new areas of settlement due to high turbidity and fast currents. The majority of the migrating forms are of a size between 5 mm and 7 mm.

Water temperature does not appear to play any important role in the breeding of the species in the region under investigation.

Studies on the distribution of the various size groups of the animals found in their burrows show that they are gregarious in habit.

Laboratory tests reveal that Sphaeroma terebrans has a high salinity tolerance capacity. The animals acclimated in 30 ‰ salinity and transferred directly or gradually to different salinity media show that their higher lethal level is 80 ‰ salinity and lower 0.5 ‰. But for these animals acclimated in 5 ‰ salinity the higher and lower lethal levels are 40 ‰ and 0.5 ‰, respectively.

Specimens of Sphaeroma terebrans were acclimated in 5 ‰ and 20 ‰ salinities and their rate of respiration in these media was determined. The regression values ('b' value) were calculated using the method of least squares to study the relationship of body size to oxygen consumption. The value of 'b' obtained in 5 ‰ salinity is 0.4463 and that in 20 ‰ is 0.3428; but these values are not significantly different statistically thereby showing the existence of similar metabolic types of the same

species living in two different salinity environments. However, these values are different from the generally known values in Crustacea which vary from 0.67 to 1.00.

The experiments on respiration show that it is difficult to assign a particular 'b' value to all animals of a particular group and sometimes even to a particular species as the value depends upon the past environmental conditions of the animal as well as experimental conditions.

The rate of respiration of the animals acclimated in 5 ‰ salinity is comparatively lower than that in those acclimated in 20 ‰.

Determination of the rate of respiration of Sphaeroma terebrans when salinity media were suddenly changed was done by transferring animals which were acclimated in 20 ‰ salinity, to higher and lower concentrations. The maximum rate of respiration was in the acclimation medium of 20 ‰ salinity and as the salinity of the medium increased or decreased the rate of respiration diminished.

In all the weight groups of animals (15 mg, 30 mg, 45 mg and 60 mg), except in 15 mg animals, a well demarcated critical level in higher media is seen starting from 40 ‰ salinity onwards and in lower salinities the critical level for all weight groups is seen from 1 ‰ salinity and below.

The decrease in the rate of respiration in the lower salinity media observed in the present studies agrees with the results reported in the studies on Balanus balanoides, B. crenatus (Krops, 1929a & 1929b); Balanus amphitrite communis and B. tintinnabulum tintinnabulum (Prasada Rao, 1965) and Maja verrucosa (von Buddenbrock, 1948).

The rate of respiration under falling oxygen tension in different salinity media showed variations. In general, the rate of respiration remained the same from 140 to 120 mm Hg pressure of oxygen.

Under laboratory conditions, the critical level of oxygen was found to be 100 mm Hg pressure of oxygen and this is comparatively a high value reported for Crustacea. Below the critical level of oxygen the rate of oxygen uptake gradually decreases.

In the same salinity medium statistically no significant difference was observed in the lethal level of oxygen for the different weight groups of animals.

In salinities 5 ‰ to 30 ‰ there was no significant difference in the lethal level of oxygen. However, below 5 ‰ and above 30 ‰ salinities there was marked change in the lethal level.

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APPENDIX I

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## A SIMPLE DEVICE FOR FILTERING AND AERATING WATER IN AQUARIA USED IN BREEDING EXPERIMENTS.

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Aeration and filtration of water in breeding tanks are essential to provide the animals with the required oxygen and also for eliminating foul gases that are formed by the decay and disintegration of excreta and other organic materials. In places where there is no running water facility it has been a problem to keep animals alive under laboratory conditions for breeding experiments and other studies. The devise described below was found well suited for simultaneous filtration and aeration of water in small breeding tanks and it is simpler, cheaper and more efficient than those sketched by Becker(1958).

The system consists of a plastic bucket with a filter bed of sand, charcoal and pebbles, one below the other and a central cylinder in which the filtered water collects. This water is then pumped into the breeding tank with the help of a jet of air (from an ordinary aerator) blown through a wide glass, polythene or rubber tube (see Fig. No. 1). As the water level in the breeding tank rises, water from it gets siphoned into the filter bed. An intermediate settling tank between the filter bed and the breeding tank is helpful in maintaining the efficiency of filtration as most of the undissolved impurities get deposited in it. The system works efficiently and it pumps back filtered and aerated water at the rate of about two and a half litres a minute. The total cost of the devise comes to about fifty rupees. In place of an aerator a manually operated blacksmith's blower could be used.

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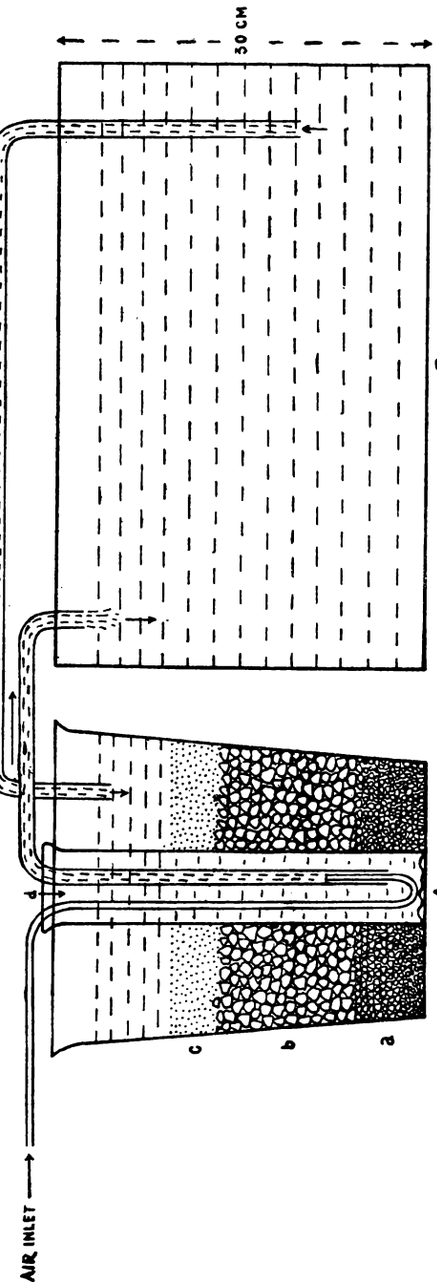
Becker, G. F. A. O. Report No. 795, 1958

Fig. No. 1

DIAGRAMMATIC SKETCH OF A DEVISE FOR FILTERING AND AERATING WATER IN BREEDING TANKS




A - FILTER BED - a - PEBBLES, b - CHARCOAL, C - SAND & d - CENTRAL CYLINDER.
B - BREEDING TANK.