

OXYGEN CONSUMPTION AS A FUNCTION OF SIZE AND
SALINITY IN *METAPENAEUS MONOCEROS* FAB. FROM
MARINE AND BRACKISH-WATER ENVIRONMENTS

BY KANDULA PAMPAPATHI RAO

Department of Zoology, Sri Venkateswara University, Tirupati, India

(Received 25 October 1957)

INTRODUCTION

It is common knowledge that in many euryhaline invertebrates the rate of oxygen consumption is related to the salinity of the medium. Several cases have been recorded where reduction in salinity of the medium results in increased oxygen consumption. Except for the studies of Schlieper and his associates, and the recent contribution of Lofts (1956), the problem of acclimatization of respiratory rate to lowered salinity in natural populations of a given species has not received much attention. The following is a contribution to this problem.

MATERIAL AND METHODS

The prawn, *Metapenaeus monoceros* Fab., is common along the coast of Madras, occurring in large numbers both in the sea and in brackish waters at river mouths. Prawns collected from the sea were kept in sea water in concrete aquaria in the laboratory, and those collected from the Cooum River, near Madras, were kept in sea water diluted to a salinity of 20‰. The salinity of sea water at the time of these experiments was 33.5‰ and that near the river mouth where the prawns were collected was 20‰. The Cooum River flows into the sea only during the monsoon period, and during the rest of the year the river mouth is blocked by a bar of sand. For this reason the salinity near the blocked mouth of the river varies from time to time, but is generally much lower than that of the sea during the greater part of the year (Gopalakrishnan, 1953). Further, the population of prawns within the brackish water is cut off from the sea by the sand bar during most of the year.

Oxygen consumption was estimated by the Winkler method as given in Welsh & Smith (1953). Oxygen consumption of each prawn was studied in four media, namely 100% (33.5‰), 50% (16.75‰) and 25% (8.4‰) sea water as well as in tap water. Change from one salinity to another was abrupt. Each prawn was allowed to remain for 15 min. after change into a given salinity before readings were started. All experiments were carried out at room temperature, which varied between 30 and 32° C. The prawns were not given any food once they were brought to the laboratory. After collection they were allowed to remain for at least 36 hr. in the aquaria before any of them were used for experimentation. The respiratory chamber was kept dark by covering it with black paper. Each prawn was killed immediately

after it had been studied in all the four media, and its wet weight was taken after the moisture on its body and its gill chambers had been removed with blotting paper. All the prawns used in these experiments were in the middle intermoult stage, other stages having been discarded.

RESULTS

Oxygen consumption in relation to body weight and the salinity of the medium

It is seen from Figs. 1 and 2 that the oxygen consumption per animal per hour increases with increasing size in both the groups of prawns and in all salinities. But this increase is not to the same degree in all the cases. This is evident from the b values given along with the graphs. But in both the cases the b value does not exhibit any systematic change in relation to the salinity of the medium.

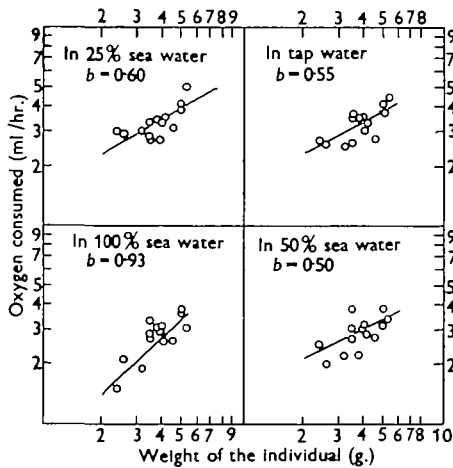


Fig. 1

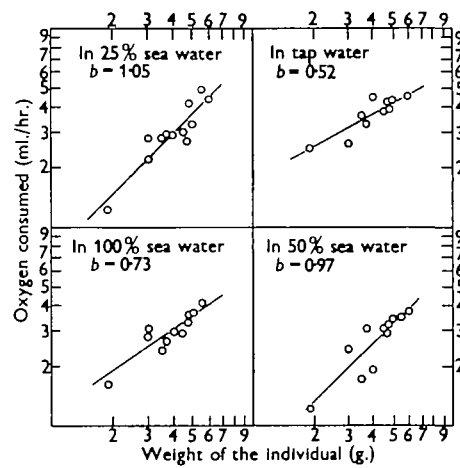


Fig. 2

Fig. 1. Oxygen consumption as function of body weight in media of different salinity, in marine *Metapenaeus monoceros*. Double logarithmic grid. Each point represents a single individual. The straight line is the best fit as per the method of least squares.

Fig. 2. Oxygen consumption as a function of body weight in media of different salinity in brackish-water *M. monoceros*. Other conditions as in the previous figure.

When marine prawns are transferred to dilutions of sea water their respiratory rate increases till it reaches a maximum value in 25% sea water, after which it falls to a lower level in tap water (Fig. 4). The brackish-water prawns behave differently. They exhibit the minimum metabolic activity in 50% sea water and their oxygen consumption increases in 100% sea water as well as in tap water and 25% sea water. It is highest in tap water and there is no indication of any adverse effect.

In Table 1 are given calculated values showing the rise in oxygen consumption with the change in salinity of the medium in individuals 3.5 g. in weight, both from the marine and from the brackish-water samples. For easy comparison, the rate in

Oxygen consumption in marine and brackish-water prawns 309

sea water for marine prawns and that in 50% sea water for brackish-water prawns has been taken as 100 and the values for consumption in other salinities are given as percentages of these basal values. Further, the difference in the osmotic concentration between the blood of the prawn and the medium in which the oxygen consumption was measured is also given in mM/l NaCl. These values are calculated from Panikkar & Viswanathan (1948). It may be seen that in the brackish-water prawns the oxygen consumption increases with the increasing difference in osmotic concentration between the blood and the medium. This is represented graphically in Fig. 5. In the marine prawns the same is true for the oxygen consumption in 50% and 25% sea water. But the adverse effect of tap water is reflected in a drop in oxygen consumption, although the osmotic difference between the blood and the medium is greatest. Further, the lowest oxygen consumption, obtained in 100% sea water, in marine prawns is in a medium which is considerably different from the blood in its osmotic concentration.

Table 1. *Data relating to a medium-sized prawn (3.5 g. in weight) from the marine and brackish-water samples, compared to show the percentage increase in oxygen consumption in relation to the osmotic difference between the internal and external media.*

Blood osmotic concentration of marine prawns is taken as 400 mM/l NaCl and that of the brackish-water prawns as 335 mM/l NaCl. Oxygen consumption is shown as percentage increase of the rate in 100% sea water for marine prawns and in 50% sea water for brackish-water prawns.

External medium	Oxygen consumption		Osmotic difference: medium-blood	Population
	ml./g./hr.	% of basal		
100% sea water	0.67	100	+175	Marine
50% sea water	0.80	119	-115	
25% sea water	0.914	136	-260	
Tap water	0.90	134	-390	
100% sea water	0.80	121	+240	Brackish water
50% sea water	0.66	100	-50	
25% sea water	0.74	112	-195	
Tap water	1.00	152	-335	

Marine and brackish-water prawns compared

A comparison of the oxygen consumption of the marine and the brackish-water populations is presented in Figs. 3 and 4. It is seen from this that at the two intermediate salinities, namely, 50 and 25% sea water, the marine prawns exhibit higher rates of oxygen consumption. The situation is reversed in 100% sea water, in which it is the brackish-water prawns that show a higher metabolic rate. A similar reversal is found in tap water also. Further, it may be seen from Fig. 5 that a lowering of the salinity of the medium involving the same degree of difference between the external and internal media results in a higher percentage increase in oxygen consumption in marine prawns as compared to the brackish-water prawns. Thus, for example, an osmotic difference of -115 mM/l NaCl (marine prawns in

50% sea water) results in the increase of oxygen consumption to 119% of that in sea water in the case of marine prawns, whereas a similar osmotic difference in the case of brackish-water prawns results only in an increase to 105% of the base value (read from the curve in Fig. 5).

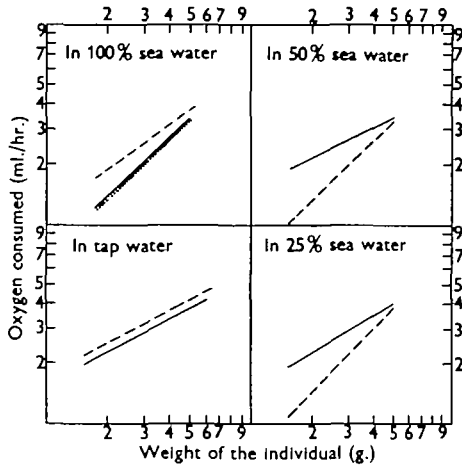


Fig. 3

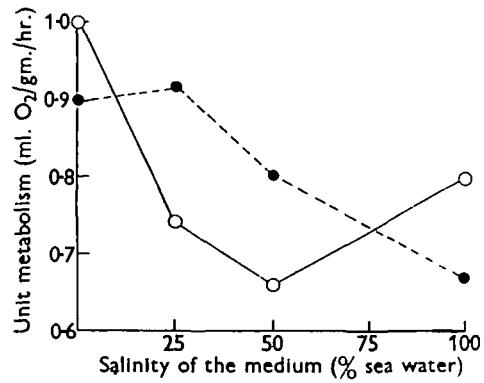


Fig. 4

Fig. 3. Comparison of oxygen consumption of marine and brackish-water prawns in media of different salinity. Curves taken from Figs. 1 and 2. Solid lines for marine prawns and broken lines for brackish-water prawns. The dotted line in upper left-hand square represents the oxygen consumption of brackish-water prawns in 50% sea water for comparison with the marine prawns in 100% sea water.

Fig. 4. Oxygen consumption as a function of the salinity of the medium in an average sized individual (3.5 g. in weight) from the marine and brackish-water samples. The values are taken from the lines given in Figs. 1 and 2. Open circles and solid line represent the brackish-water prawn and solid circles and broken line represent the marine prawn.

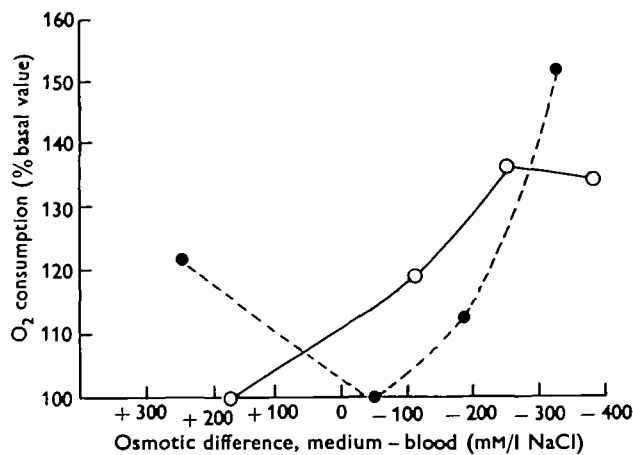


Fig. 5. Oxygen consumption (% of basal value) as function of osmotic difference between the internal and external media in an average-sized individual (3.5 g.) from the marine and brackish-water samples. Open circles and solid line represent the marine prawn and closed circles and broken line represent the brackish-water prawn.

DISCUSSION

In general the brackish-water prawns appear to have higher b values. But there is no systematic trend in b values with change in the salinity of the medium in either population. The high b value reported here for brackish-water prawns in 25% sea water may have resulted from changes in physiological factors other than size *per se*. In view of these facts it is difficult to emphasize the biological significance of b .

The marine population of the prawn, *M. monoceros*, belongs to the second group of Bock & Schlieper (1953). It is known that *M. monoceros* exhibits active regulation of chloride (Panikkar & Viswanathan, 1948), and the increase in oxygen consumption in media of lowered salinity may be to some degree a reflexion of this regulation. But Potts (1954) has shown that in *Eriocheir* only a very small fraction of the increased oxygen consumption represents osmotic work done. Gross (1957) has suggested that a great part of the increased oxygen consumption in hypotonic media might be the result of increased locomotor activity. But it is known that in some poikilosmotic animals even tissue respiration is higher in lowered salinities (Bock & Schlieper, 1953; Schlieper, 1955), in individuals which normally inhabit media of lowered salinity. Further, Gopalakrishnan (1953) has shown that when a prawn is subjected to a constant flow of hypotonic medium while being kept in a tight glass jacket which does not permit any limb movement, its oxygen consumption increases over a period of 16 hr. and keeps steady thereafter (a result due, perhaps, to cuticular permeability). Consequently, it is not clear what the increased metabolic rates mean. But Fig. 5 is instructive inasmuch as it shows that the percentage increase in oxygen consumption is related to the osmotic difference between the blood and the medium.

In their respective natural media both the groups of prawns have about the same respiratory rate (Fig. 3). But brackish-water prawns, living in a hypotonic medium, exhibit their lowest rate of oxygen consumption in 50% sea water, while in the same medium marine prawns show an increase in their oxygen consumption which is 119% of their basal. Likewise marine prawns, naturally adapted to a hypertonic medium (100% sea water), exhibit their lowest oxygen consumption in that medium, although the gradient between the osmotic concentration of the external medium and the blood is as high as +175 mM/l NaCl, whereas brackish-water prawns in 100% sea water have a respiratory rate which is 121% of the basal. The fact that the oxygen consumption increases on transfer to a hyper- or hypotonic medium (as exhibited by brackish-water prawns in 100% sea water and marine prawns in 50% sea water), and that on prolonged sojourn in such a medium there is a marked tendency towards lowering of the oxygen consumption to its normal level (as is well exemplified by the lowered oxygen consumption of the marine prawns in 100% sea water) indicates that, besides the normal osmotic regulation resulting in an approximation of the external and internal media, a metabolic homeostatic mechanism may be operating in relation to osmotic regulation consequent upon osmotic stress. It is possible that the long-term metabolic adjustment

may be secondary to long-term acclimatization of blood electrolytes and/or permeability (both active and passive). Whether such a homoeostatic mechanism is to be expected only amongst active regulators is an open question. But the fact that in poikilosmotic organisms, such as *Asterias rubens* (Bock & Schlieper, 1953) and *Mytilus edulis* (Schlieper, 1955) there is no such metabolic homoeostasis in media of different salinity, and thus of different osmotic pressure, is of interest in this context.

Eliassen (1952) found an increase in oxygen consumption in *Artemia salina* when the salinity of the external medium was decreased, and this was most marked in young nauplii, being less evident or even almost absent in the larger individuals. In these experiments the change to a lowered salinity was not abrupt and the larger individuals have grown to that size in media of lower salinity in which they were tested. *Artemia* takes about 4 weeks to reach maturity, and perhaps in this time there was an adaptation to lowered salinity and such an adaptation is likely to be a reason for the absence of any significant differences in oxygen consumption amongst adults in different salinities.

SUMMARY

1. The oxygen consumption in relation to the salinity of the medium has been studied in a marine and a brackish-water population of the prawn, *Metapenaeus monoceros* Fab.
2. It has been shown that the regression coefficient of oxygen consumption against weight is not the same for media of different salinity and for the two populations.
3. In both the groups of prawns an increase in the oxygen consumption was observed, with a decrease in the salinity of the medium below that of the habitat. But the marine prawns showed higher rates in 50 and 25% sea water compared to the brackish-water prawns. On the other hand, the brackish-water prawns exhibited a higher rate of oxygen consumption in 100% sea water and in tap water.
4. It is suggested that these differences might be due to (i) an osmotic adaptation, and (ii) the operation of a metabolic homoeostatic mechanism in relation to osmotic regulation.

My sincere thanks are due to the Director, Zoological Research Laboratory of the University of Madras, for giving me the necessary facilities in his laboratory for the conduct of this investigation. To Dr S. Krishnaswamy my thanks are due for several courtesies extended to me during my stay in that laboratory. I am especially grateful to Dr Theodore H. Bullock of the University of California at Los Angeles, Prof. V. B. Wigglesworth of the University of Cambridge, Dr Erik Zeuthen of the Zoophysiological Laboratory at Copenhagen, Dr W. J. Gross of the University of California at Riverside and Dr Paul Dehnel of the University of British Columbia at Vancouver for critically reading through the manuscript of this paper and offering helpful suggestions.

REFERENCES

- BOCK, K. J. & SCHLIEPER, C. (1953). Über den Einfluss des Salzgehaltes im Meerwasser auf den Grundumsatz des Seesternes *Asterias rubens* L. *Kieler Meeresforsch.* 9, 201-12.
- ELIASSEN, E. (1952). The energy metabolism of *Artemia salina* in relation to body size, seasonal rhythm and different salinities. *Univ. Bergen Arb. naturv. R.* no. 11, 1-17.
- GOPALAKRISHNAN, V. (1953). Studies on the biology of Madras Penaeids. Doctoral Dissertation, University of Madras.
- GROSS, W. J. (1957). An analysis of response to osmotic stress in selected decapod crustacea. *Biol. Bull., Woods Hole*, 112, 43-62.
- LOFTS, B. (1956). The effects of salinity changes on the respiratory rate of the prawn *Palaemonetes varians* (Leach). *J. Exp. Biol.* 33, 730-6.
- PANIKKAR, N. K. & VISWANATHAN, R. (1948). Active regulation of chloride in *Metapenaeus monoceros* Fabricius. *Nature, Lond.*, 161, 137.
- POTTS, W. T. W. (1954). The energetics of osmotic regulation in brackish- and fresh-water animals. *J. Exp. Biol.* 31, 618-30.
- SCHLIEPER, C. (1955). Über die physiologischen Wirkungen des Brackwassers. *Kieler Meeresforsch.* 11, 22-33.
- WELSH, J. H. & SMITH, R. I. (1953). *Laboratory Exercises in Invertebrate Physiology*. Minneapolis.