EFFECT OF SALINITY, TEMPERATURE AND OXYGEN PARTIAL PRESSURE ON THE RESPIRATORY METABOLISM OF *PANULIRUS POLYPHAGUS* (HERBST)

H. MOHAMAD KASIM

Research Centre of Central Marine Fisheries Research Institute, Tuticorin.

ABSTRACT

The lethal oxygen levels, time to death, total oxygen consumed and the metabolic rates of *Panulirus polyphagus* (Herbst) are estimated at different salinities, temperatures and oxygen partial pressures after acclimating the lobsters to 17, 32, 39 and 50 ppt at ambient temperatures 22.5, 22.1, 28.1 and 20.1°C, respectively. The incipient lethal salinities are obtained graphically from lethal oxygen levels and time to death at different salinities. The metabolic rate is uniformly high within oxygen independent zone of higher pO_2 and, in oxygen dependent zone, it is curtailed drastically. Subsequently, the low oxygen partial pressure becomes lethal. As a means of compensation, the metabolic rate in this species decreases at extreme salinities and tends to increase at intermediary salinities. The influence of salinity acclimation and temperature on the metabolic rate is evident. It is suggested that factors other than salinity gradient may also be sought in order to explain the metabolic pattern of this species.

INTRODUCTION

The effect of salinity, temperature and oxygen on the physiology of aquatic organisms are discussed elaborately by Prosser and Brown (1961) and Kinne (1970). Among the studies on the respiratory physiology, the limiting effect of oxygen partial pressure (pO_2) upon oxygen consumption is considered as an important aspect, especially in view of the present importance given on the culture of aquatic organisms in sewage and waste waters. Present study deals with the effect of salinity, temperature and oxygen partial pressure on the oxygen consumption in an economically important spiny lobster, *Panulirus polyphagus* (Herbst).

MATERIAL AND METHODS

The material used for the present study was the young ones of spiny lobster, *Panulirus polyphagus* (Herbst), measuring 39.3 ± 5 mm carapace length and weighing 45.3 ± 11.5 g, obtained from trawl landings at Veraval. Collectively, 132 lobsters were acclimated to 17, 32, 39 and 50 ppt at ambient temperatures 22.5 ± 0.9, 22.1 ± 1.2, 28.1 ± 1.8 and 20.1 ± 1.7°C, respectively, and tested at different salinities ranging from that of fresh water to 78.7 ppt and at above mentioned different temperatures. The temperatures were not controlled and therefore there was high fluctuation during different period of acclimation and test. However, the tests were carried out within a few hours' duration of time (0.5 to 18.5 h) in a day and the fluctuation in test temperature was ± 1°C. The lobsters were taken to low and high acclimation salinities by gradual change in the salinity every day by adding either fresh water or concentrated sea water as needed. The test lobsters were fed by frozen shrimp meat daily during acclimation and starved during experimentation in order to maintain the physiological conditions almost uniform to avoid contamination of the test medium. The data on the lethal oxygen levels, time to death, total oxygen consumed, lethal salinity and the rate of oxygen consumption were gathered.

Always uniform-sized lobsters were used for one set of (triplicate) experiments. Glass jars of 3 l capacity with thermocol lids (not air tight) and with provision to tap out water samples were used as respirometers. The test medium of required salinity was prepared in advance and aerated overnight by an electrical aerator through coral stone before transferring into the respiration chambers. Then the lobsters were introduced one in each respiration chamber and the water surface was covered with sufficient quantity of liquid praffin to prevent the gaseous exchange from atmosphere. At regular intervals, ie., 15, 30 and 60 min., water samples were drawn from the respirometer to estimate the oxygen content, and the experiments were continued till the lobster died owing to anoxia. The time interval for water sampling was kept short at lethal salinities and increased at nonlethal salinities. The lobsters were assumed to have died when they ceased to respond to external stimuli and all the movements of body parts stopped.

The partial pressure of oxygen, which had been close to air saturation (160 mm Hg) at the start of the experiment, got gradually reduced owing to the oxygen uptake by the lobster, and this in turn affected the oxygen consumption of the lobster. The oxygen partial pressure (pO_2) mm Hg) at different levels of experimentation was estimated as per the following equation:

$$pO_2 = \frac{160}{O_2 \text{ content in water at test temperature}} \times O_2 \text{ content in test medium}$$

Modified Winkler's method (Stickland and Parsons 1968) was employed to estimate the oxygen content in water samples and the silver nitrate method of Knudsen (Stickland and parsons 1968) was used to estimate salinity.

Results and Discussion

Lethal salinity: As the experiments on the respiration of this species were conducted in salinities ranging from that of fresh water to 78.7 ppt, the available data provide information not only on the respiration but also on the lethal levels of salinity and oxygen. The estimates on the incipient lethal salinities were obtained graphically from the data on the lethal oxygen and time to death, as shown in Fig. 1. The incipient lethal salinity is the dose at which 50% of the population suffers mortality (Fry 1971, Kasim 1979). The curves fitted through the plots of lethal oxygen and time to death cross at both the extreme salinities and these junctures indicate the lethal salinities. The incipient lethal salinities thus obtained are 3, 11, 15 and 25 ppt at lower levels and 45, 55, 60 and 60 ppt at higher levels for acclimations 17, 32, 39 and 50 ppt respectively. It appears that there was no gain in salinity tolerance at higher salinity acclimations as the incipient lethal salinities for 39 and 50 ppt are the same; ie., 60

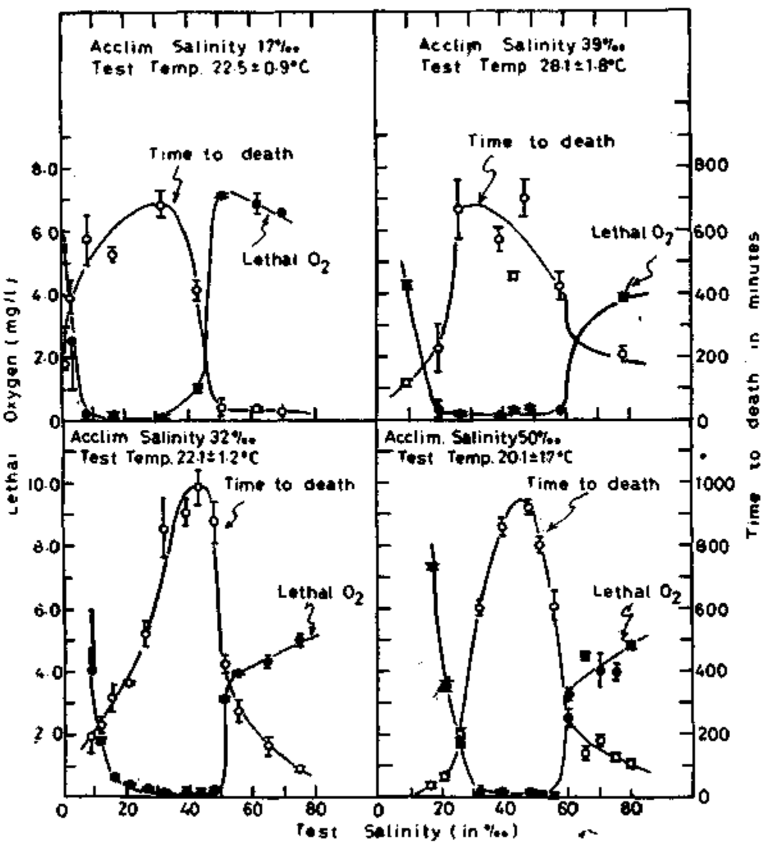

FIG. 1. The relation between the lethal oxygen levels with one SD and time to death with one SD for *Panulirus polyphagus* acclimated to 17, 32, 39 and 50 ppt and tested in different salinities and temperatures.

ppt. The area of salinity tolerance for this species is shown in Fig. 2 by plotting the incipient lethal salinities against the acclimation salinities, where the 45° angle lines differentiate the area of upper and lower salinity tolerance. The area of lower salinity tolerance appears to be wider than the upper salinity tolerance.

Lethal oxygen and time to death: The lethal oxygen levels, shown in Fig. 1, were lowest in the tolerable range of salinities and tended to increase in the extreme salinities in all acclimations. Conversely, as the lobsters survive better in tolerable salinities, it takes longer time to die in these than in extreme salinities, where the lobsters die in shorter time. The lethal oxygen levels and time to death obtained at the respective lower and upper incipient lethal salinities are as below:

Acclim. salinity	17ppt		32ppt		39ppt		50ppt	
Incipient lethal salinity	3ppt	45ppt	11ppt	55ppt	15ppt	60ppt	25ppt	60ppt
Lethal oxygen	3.7	2.0	2.3	3.6	1.7	2.5	1.7	2.5
Time of death	370	200	230	360	170	250	170	250

It may be seen from the above table that the lethal oxygen levels and time to death are directly proportionate to the incipient lethal salinities of all acclimation except 17 ppt, in which it is inversely proportionate. This shows that the lobsters survive better in hyperosmotic conditions, indicating their euryhaline characteristics as in the case of gammarid, *Echinogammarus berilloni* (Ciavatti and Vincent 1982).

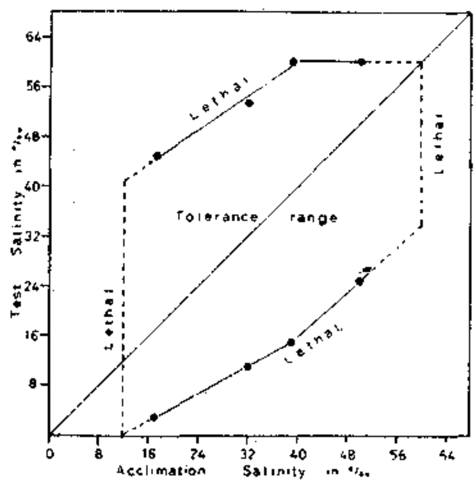

FIG. 2. The salinity tolerance range of *Panulirus polyphagus* obtained from the data on lethal oxygen levels and time to death at different salinities.

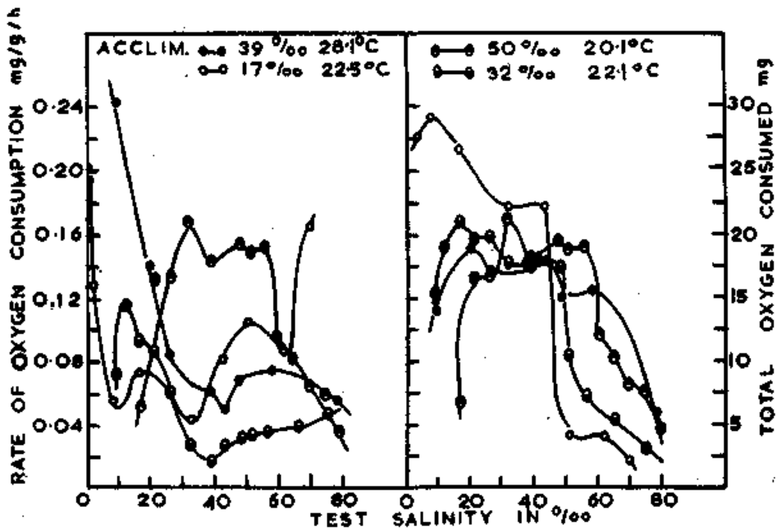

FIG. 3. The rate of oxygen consumption (mg|g|h) and total oxygen consumed (mg) by the lobster *Panulirus polyphagus* acclimated and tested in different salinities and temperatures as indicated.

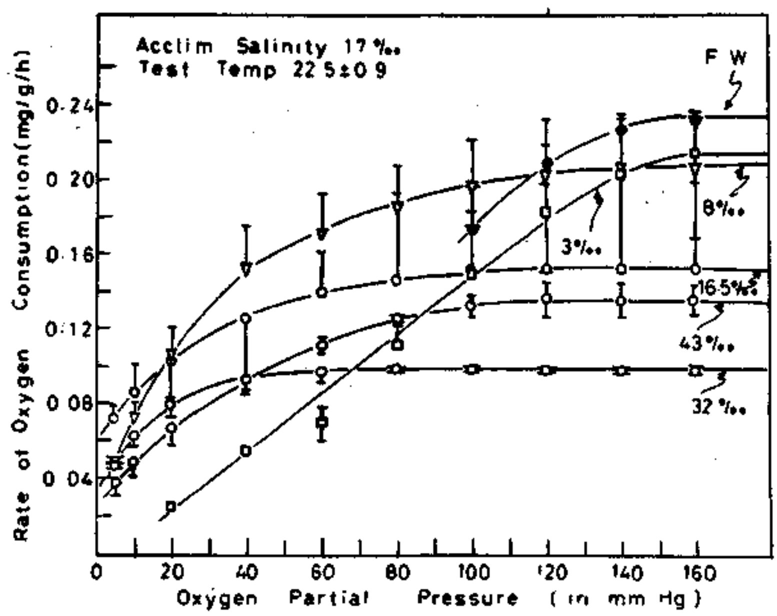

FIG. 4. Rate of oxygen consumption with one SD (mg|g|h) at different salinities indicated and oxygen partial pressures (pO2 mm Hg) for *Panulirus polyphagus* acclimated to 17 ppt.

Rate of oxygen consumption and total oxygen consumed: The rate of oxygen consumption was always lower at optimum salinities and higher at extreme salinities in all acclimations as is shown in Fig. 3, wherein the data on the rate of oxygen consumption and total oxygen consumed are given. Further, it increased in consonance with the rise in temperature as the metabolic rate was lower in acclimation 50 ppt at 20.1°C than in 39 ppt at 28.1°C. The highest metabolic rate was recorded in salinities above 40 ppt for acclimation 17 ppt. The results obtained for these lobsters are comparable with the results obtained for *Penaeus notalis* in different salinities and temperatures (Ramos Trujillo and Oliva Suarez 1984). Unlike in the case of *Penaeus indicus* (Kutty et al 1971), the influence of salinity acclimation on the metabolic rate is evident in lobsters. It is possible that factors other than osmotic gradient should be considered in order to explain adequately the respiratory physiology of *P. polyphagus*.

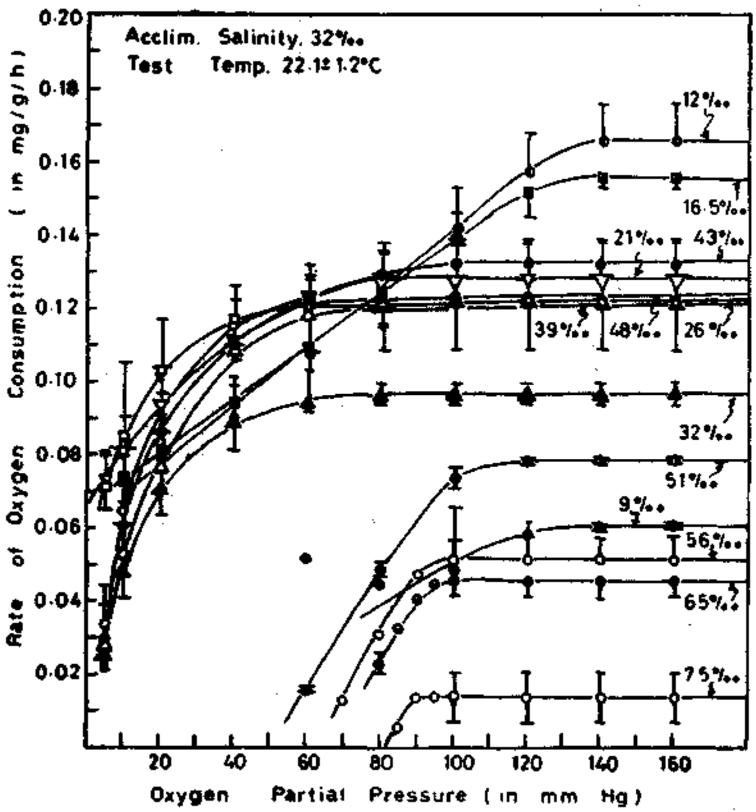

FIG. 5. Rate of oxygen consumption with one SD (mg|g|h) at different salinities indicated and oxygen partial pressures for *Panulirus polyphagus* acclimated to 32 ppt.

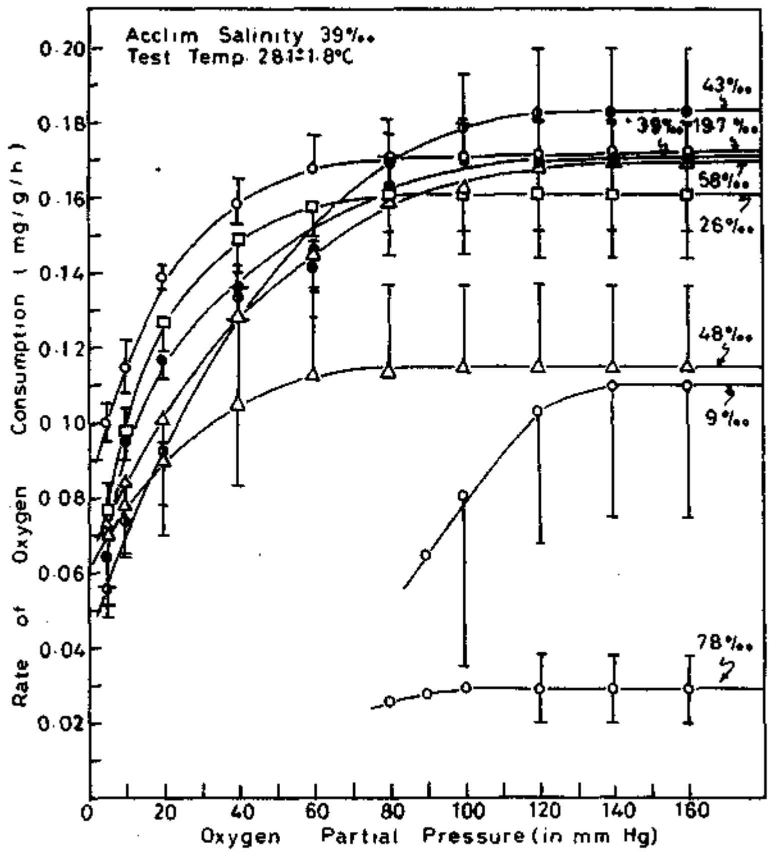

FIG. 6. Rate of oxygen consumption with one SD (mg|g|h) at different salinities indicated and oxygen partial pressures for *Panulirus polyphagus* acclimated to 39 ppt.

Invariably, the total oxygen consumed by the lobsters was higher in low test salinities and it gradually increased with higher test salinities. The total oxygen uptake was inversely proportionate with the salinity acclimation at test salinities up to 40-45 ppt and, in higher test salinities, it was almost directly proportionate. In general, the cold-acclimated lobsters (50 ppt at 20.1°C) consumed more oxygen than the warm-acclimated ones (39 ppt at 28.1°C).

Oxygen partial pressure: The data on the rate of oxygen consumption obtained at different salinities and oxygen partial pressures were treated initially on arithmetic graphs, to obtain standard rate of oxygen consumption uniformly at different pO_2 from 5 to 160 mm Hg at an interval of 5 mm Hg. These data are shown in Fig. 4, 5, 6 and 7 for acclimations 17, 32, 39 and 50 ppt, respectively. The curves fitted through these plots indicate that the metabolic rates are always high in higher pO_2 in all salinities. These higher metabolic rates tend

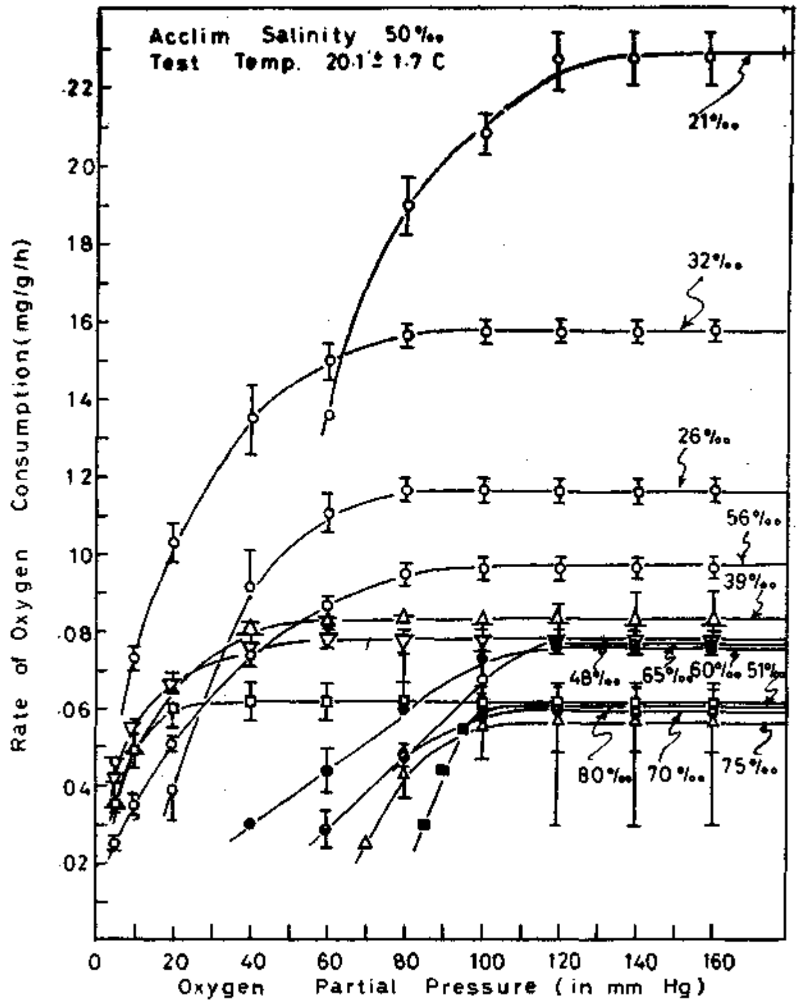

FIG. 7. Rates of oxygen consumption with one SD (mg/g/h) at different salinities indicated and oxygen partial pressures for *Panulirus polyphagus* acclimated to 50 ppt.

to decline subsequently at a particular pO_2 where the lobsters enter into the oxygen-dependent zone and consequently get exposed to metabolic stress. This particular pO_2 which differentiates the oxygen independent and dependent zones has been known as the 'Critical tention point' (Job 1959), since below this level the lobsters die.

In intermediary nonlethal salinities, irrespective of the metabolic rate, the lobsters were observed to survive in oxygen partial pressures as low as 5 mm Hg, whereas in extreme lethal salinities they collapsed in higher oxygen partial pressures owing to added osmotic stress (Figs. 4 to 7). Further, the metabolic rates in intermediary nonlethal salinities were at the optimum levels in different oxygen partial pressures and in extreme lethal salinities the metabolic rates were either very high or very low, depending on the acuteness of the lethality. Such varying metabolic rates at different salinities have been reported in zoea and adult *Macrobrachium olfersii* (McNamara et al 1982) and in gammarid, *Echinogammarus berrilloni* (Ciavatti and Vincent 1982).

When the acclimation temperatures are taken into consideration, the metabolic rates of the warm-acclimated lobsters (39 ppt at 28.1°C) were higher and the cold-acclimated lobsters (50 ppt at 20.1°) were lower compared to the metabolic rates of the lobsters acclimated to 17 ppt at 22.5°C and 32 ppt at 22.1°C. It is well known that the metabolic rate of the cold-blooded animals are directly proportionate to the temperature within the normal tolerance range (Sutcliffe 1984, Ramos Trujillo and Oliva Suarez 1984). In general, it is also well established among the poikilotherms that they depress the metabolic rate at extreme lethal levels and increase the same at intermediary optimum levels as a means of physiological compensation (Prosser 1958, Precht 1958 and Parvatheeswararao 1970).

Acknowledgements

The author is immensely thankful to Dr. E. G. Silas, former Director, C. M. F. R. Institute, for his keen interest in this study and to Dr. P. Vedavyasa Rao, Head of P. N. P. Division, for critically going through the manuscript and offering useful suggestions.

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