Respiratory Metabolism of Crabs from Marine and Estuarine Habitats.

I. Scylla serrata*

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Abstract

Nearly 500 crabs, Scylla serrata (Forskal) (family Portunidae), ranging in wet weight from 0.2 to 14.0 g, were acclimated to 27° and 35° and their respiratory metabolism under water and on exposure to air at test temperatures ranging from 16° to 38° was studied. In aquatic respiration, the response to temperature of crabs acclimated to a temperature of 16° C is statistically significant, and directly related to their weight. Smaller crabs did not survive at the warm acclimation level of 35° C. The metabolic rates of cold-adapted S. serrata are higher than those of warm-adapted ones. The effect of acclimation to aerial respiration on crabs acclimated to cold temperature varied slightly between large and small crabs. The aerial respiration rate was less than a tenth of the aquatic rate for all sizes. The response of S. serrata to warm acclimation in air has been found to be almost opposite to its response in water.

Introduction

Knox (1956) and Prosser and Brown (1961) have reviewed the extensive literature on metabolism and adaptations to environmental conditions in poikilotherms. A comprehensive account of the effect of temperature as an environmental factor on cold-blooded animals has been given by Precht (1958). Prosser and Brown (1961) have demonstrated the relationship between temperature and metabolic rate (R-T). Our knowledge of the respiratory metabolism in crabs from temperate regions is based on the works of Weymouth et al. (1944), Roberts (1957) and Dehnel (1960), who have correlated respiration with size, temperature and salinity. Teal (1959) showed the relationship between respiration of crabs and their environment. Vernberg (1959) investigated the physiological variation between tropical and temperate-zone fiddler crabs of the genus Uca. The influence of temperature upon oxygen consumption of several arthropods has been studied by Edwards (1946).

Similar studies on the relationship between metabolism and environment in tropical poikilotherms are inadequate. It was felt that an analysis of the effect of temperature on 3 tropical species of crabs which are ecologically distinct from one another might yield valuable information, especially as regards the process of transition from aquatic to terrestrial life.

The most dependable assessment of the stress and strain imposed on organisms by their environment can be made by studying changes in the metabolism of the whole individual concerned. Hence, oxygen uptake, which is frequently used as an index of metabolic activity of organisms, forms the basis of assessment in such studies. In measuring oxygen consumption, the state of activity is known to influence oxygen uptake considerably (Spoor, 1946; Fry, 1947; Brett, 1962). In the rapid, hourly fluctuations of the tropical estuarine-intertidal environment, the metabolic responses of an animal are bound to be reflected in its “routine” metabolism also. Therefore, the data presented here refer to the metabolism of crabs in this routine state of activity only.

Aquatic animals exposed to oxygen-poor water, or to aridity, are known to possess accessory breathing devices. Pearse (1929) has related the gill number and habitat of crabs according to the ecological zones they occupy, but he does not show how the oxygen demand is met. In parallel work on air-breathing fish, it has been demonstrated that, in some cases, the interpolation of respiratory rate of the accessory organ causes a clear inflection in the size versus oxygen uptake curves; the accessory respiratory organ distinctly and progressively (although not entirely) takes over the burden of respiration from the gills (Carter, 1931; Jeukem, 1957; Jalal, 1962; Kottil, 1963).

Therefore, an assessment of this proportionality in the modes of respiration was attempted to determine the progression in which aerial respiration supplements aquatic respiration. The gill surface area was also measured, and related to metabolic rate and to the...
efficiency of oxygen uptake in air and at various partial pressures of oxygen in water.

**Material and Methods**

*Scylla serrata* (Forskal) is entirely waterbound, living in estuaries and on soft oozy or sandy bottoms of the sea. It attains a very large size (2 kg) as an adult.

Individuals were collected and brought to the laboratory, where they were sorted into different groups and kept in glass tanks. The salinity of the sea water in the tanks was maintained at 35%. The average temperature was 27° ± 0.5 °C and the pH range of water varied from 7.0 to 7.5. An unlimited standard mixture of seaweeds, fish, prawn and worms was supplied to the crabs. The weights of crabs used in experiments ranged from 0.2 to 14.0 g. The crabs were starved for more than 12 h before use in the experiments; only intermolt specimens were used.

**Aquatic Respiration**

The range of experimental temperature was fixed after determining the upper and lower lethal temperatures, following the method of Teal (1959). One series of experiments was performed by acclimating the crabs to room temperature (27 °C) and testing them at 16°, 20°, 25°, 27°, 31°, 35° and 38 °C, and a second series acclimating them to 35 °C and testing them at 35°, 27° and 16 °C.

Routine oxygen uptake was measured by the Winkler method. Glass beakers of different capacities ranging from 100 to 1000 ml were used as respiration chambers according to the size of the crab. Sea water of 35% S was aerated to saturation value at the various test temperatures. The volume of water used in the experiments ranged from 100 to 800 ml, according to the size of the specimen, and was covered with a 2 cm thick layer of paraffin. All the respiration chambers were kept in an insulated water bath at a constant temperature, which was maintained thermostatically to within ±0.3 °C.

The rate of oxygen consumed per hour was calculated from the rate of fall of dissolved oxygen in the water in the respiration chamber, and expressed as ml/h per crab. The experiments were continued for 3 h, and the maximum oxygen consumption rate obtained was recorded in each experiment (cf. Job, 1955; Kottil, 1963).

In a separate series of experiments at 27 °C, the rate of oxygen uptake by each specimen was measured at different oxygen tensions, following the methods described by Hall (1929), Keys (1930), Graham (1949), Job (1955) and Kottil (1963), until the oxygen in the water reached the asphyxial level.

**Aerial Respiration**

Measurements of respiration in air were made with simple pressure-sensitive Warburg-type respirometers after the methods of Teal (1959) and Kottil (1963).

Wide-mouthed cylindrical staining jars of about 250 ml capacity, or specimen tubes of about 100 ml capacity, according to the size of the crab, were used as respiration chambers. These chambers were kept inside an insulated waterbath (at the required temperature) and the experiments were started when the temperature inside the chamber had equalised with the temperature in the bath. A vial containing strips of filter paper soaked in 15% potassium hydroxide solution was suspended inside the respiration chambers to absorb the carbon dioxide given out by the crabs.

Humidity in the respiration chamber was maintained by introducing a few drops of sea water before the crab was sealed in. The entire experiment lasted 3 h, and the average rate of oxygen consumption/h per crab was calculated.

**Results and Discussion**

Oxygen-consumption rates were obtained from crabs acclimated either to 27 °C (cold) or to 35 °C (warm) and measured at the various test temperatures with the crab respiring in water or in air. The lines of best fit were drawn according to the principle of least squares. Edwards (1946), Vernberg (1959) and Dehnel (1960) found that, among insects and crustaceans, the log-oxygen consumption and log-weight data could be fitted into a straight line. In their experiments, the values of the regression obtained over various temperatures showed no trend, i.e., ascending or descending order with parallel changes in the temperature segments. The data in the present study were no exception. Analysis of covariance (Snedecor, 1961) was, therefore, carried out on the data. In the analysis of covariance, the F ratio, significant at the 5% level only, was as a rule, taken into consideration. In a series where the F ratio was significant, and where there was also a positive linear trend along the slopes, the arithmetical mean was drawn for the temperature and regression coefficient values. The metabolic rates were obtained by drawing the respective slopes through the respective common means for weight and oxygen uptake at the various experimental temperatures.

In cases where the F ratios were not significant, or where the F ratios were significant but the regression coefficient values showed no positive linear trend with increasing temperature, the common slope alone was taken and drawn through the respective mean points for weight and oxygen consumption. Thus, in this analysis, metabolic rates for the different sizes