ON THE DESICCATION, TEMPERATURE AND SALINITY TOLERANCES OF SOME TROPICAL LITTORINIDS

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ABSTRACT

Experimental studies were conducted on two tropical intertidal littorinids, namely Nodilittorina leucosticta (Philippi) and Litorina undulata (Gray). N. leucosticta possesses a greater degree of tolerance to temperature and salinity variations and a lower rate of water loss, when compared to L. undulata. These findings are in conformity with the positions occupied by these two species on the intertidal belt, N. leucosticta occupying comparatively higher positions than L. undulata on the intertidal belt. A relationship is, thus, discernible, between zonal distribution and reaction to environmental stresses.

INTRODUCTION

The organisms inhabiting the intertidal zone are subject to widely fluctuating environmental conditions. These can tolerate comparatively more extreme conditions than other marine organisms. The tolerance limits can be correlated to their position in the intertidal belt. Much work has been done on the resistance adaptations of intertidal animals and a great volume of literature has accumulated on this subject (Vernberg and Vernberg, 1972). But most of these works pertain to animals of subtropical and temperate waters. Very little is known regarding the tolerance limits of the tropical animals to high temperature, wide fluctuations of salinity, prolonged periods of desiccation, low oxygen tensions and to pollutants in the ambient medium. Hence a study of these aspects was undertaken on certain selected intertidal littorinids inhabiting different positions in the intertidal belt of a rocky shore near Trivandrum. The work reported in the present paper is a part of an elaborate study designed to examine the nature of resistance adaptations of marine invertebrates.

MATERIALS AND METHODS

Littorinids* belonging to two species Nodilittorina leucosticta and Litorina undulata collected from the rocky shore of Kovalam during the period May–December, 1975 were used for the study. Nodilittorina leucosticta occurs on the upper levels (1.0 to 1.75 m above low water level) and Litorina undulata at comparatively lower levels (0.5 to 1.5 m below high water level) of the intertidal zone. Specimens were brought to the laboratory in plastic buckets and the following experiments were carried out after keeping them in the laboratory for twenty four hours. Sets of about 20–25 numbers of snails were dried with blotting paper and subsequently placed in small petridishes of known weight. The wet weight of the snails was then determined by weighing the dishes containing them. After weighing, the dishes were placed in a desiccator in which the snails were dried above concentrated

* Identified by Dr. Joseph Rosewater, Smithsonian Institution, Washington.
sulphuric acid (Davies, 1969). The animals were weighed again at specific intervals and loss of water estimated, and the snails were then placed in sea water and the number of living snails recorded. A snail was considered alive when some response was shown to mechanical teasing.

Littorinids for the study of salinity tolerance were acclimatised in the laboratory aquaria for 12 hours before using for the tests. Water of different grades of salinity ranging from 3.43 to 39.80°/oo were used. Filtered sea water was suitably diluted by the addition of well water. Higher grades were prepared by the addition of crude common salt obtained by the evaporation of sea water. The salinity of the solution was tested before and after each test by Mohr–Knudsen method. The experiments were carried out in 1 litre glass troughs which were cleaned thoroughly before use, filled with the solutions of different grades, and aerated once in two hours. To avoid evaporation as much as possible, the containers were covered with glass plates and the loss, if any, was made up by the addition of fresh water. A control was also run parallel to these using normal sea water. In all the experiments the reactions of the animals were noted at intervals.

For experiments on temperature tolerance sets of ten active specimens were put into large thermos flasks containing sea water at particular temperatures. Notes were recorded on the nature of activity of these in different temperatures. All tests were repeated four times and the results shown represent the average values.

RESULTS AND DISCUSSION

One of the serious problems confronted by intertidal organisms is desiccation especially for those sessile animals occupying positions towards the high tide mark. Most of these animals are able to tolerate this stress for long periods of time and their resistance to desiccation appears to be related to vertical zonation. Davies (1969) suggested that permeability to water of mantle tissues could be a factor in water loss.

The data obtained from the tests on the effects of desiccation are given in Fig. 1. The loss in weight for each 24 hr period was calculated as a percentage of the initial weight of the soft parts. It was noticed that there was a rapid rate of water loss initially after which the rate remained fairly constant. The high initial rate could probably be attributed to evaporation of superficial and shell water.

The data also suggest that the 2 species of littorinids show differences in the respective rate of water loss before reaching the lethal level in water loss. This differential rate is in fact a reflection of the corresponding levels the snails
occupy in the intertidal belt. It is thus clear that there is a relationship between the exact habitat of the these species and the nature of water loss, from the body indicating adaptive specialization to occupy positions where interspecific competition is comparatively less in the crowded conditions of the intertidal zone. *L. undulata* which occurs at lower levels of the intertidal belt being more sensitive to desiccation than those at higher levels, shows maximum rate of water loss. *N. leucosticta* shows evidence of greater resistance to water loss and this would explain its position high up in the intertidal zone. *L. undulata* loses water fairly rapidly until about 13.32% of the weight of the snail has been lost. After this the trend indicates a marked reduction in the rate of water loss. The fact that in the case of snails which have lost their vitality, this reduction in the rate of water loss occurs after a much higher percentage of water has been lost, and that in the case of the dead snails the water loss is continuous and steady, makes it probable that in this species the opercular mechanism together with the low degree of porosity of the shell provide efficient protection against excessive evaporation. In the other species such a sudden change in rate of water loss was not noticed.

There is a good relationship between rate of water loss and the zonal distribution on the rocky shore. In fact *L. undulata* which lost water most rapidly in the tests occupies comparatively lower positions in the intertidal zone whereas *N. leucosticta* occupies higher zones and are mostly exposed to the air which accounts for this adaptation. In the first place it can withstand a water loss of up to about 29% and in the second place it can decrease the rate of water loss efficiently which is probably done by withdrawing into the shell and closing of the shell with the operculum. The ability of this species to inhabit the highest intertidal levels is thus dependent upon these protective mechanisms. The levels occupied by the other species are also related to the amount of water loss they can endure. Thus tolerance to desiccation is reflected in the nature of vertical distribution of animals in the intertidal belt.

Most of the studies conducted hitherto were concerned with the determination of average times of exposure for organisms inhabiting different levels (Colman, 1933; Moore, 1936; Grubb, 1936; Hevatt, 1937; Bokenham, Neuglbauer and Stephenson 1938). It was shown that organisms from higher levels withstood desiccation better than those from lower levels (Ferronniere, 1901). Isaac (1933, 1935) and Zeneveld (1937) have obtained data on the rate of water loss in relation to intertidal position. The present study while confirming the results of these authors also extends it to tropical animals and attempts to explain the mechanism by which some species regulate their water loss.

Tolerance to high temperatures is one of the chief characteristics of the intertidal organisms especially those living in the upper areas of this region. Some intertidal animals distributed over a wide latitudinal range are resistant to very low temperatures as well as

![Figure 2a](image-url)

*Fig. 2a.* Percentage mortality of *Littorina undulata* in different temperatures.
high temperatures (Vernberg and Vernberg, 1972).

The results obtained for the temperature resistance of two species are shown in Figs. 2a & 2b. *N. leucosticta* reaches such high levels on the shore that some of the individuals are washed only by the waves during high tide when the wave action is considerable. The lethal temperature for submerged individuals of this species appears to be fairly high, i.e., about 60°C. For *L. undulata* the lethal point is around 55°C.

Several investigators working on marine intertidal molluscs have demonstrated different lethal temperatures for species inhabiting different levels on the shore (Gowenlock and Hayes, 1926; Gowenlock, 1926; Henderson, 1929). It was also noticed that differences occur even between the temperatures lethal to individuals of the same species collected from different levels (Gowenlock and Hayes, 1926). Gowenlock and Hayes (1926) determined the temperature lethal to snails when submerged. Although none of them seem to have taken temperature readings in the different habitats of the snails dealt with, it is very likely that the temperature range differed in the several habitats during low water, and that these differences would show a correlation with the differences in the lethal temperatures.

Although it is not possible to state whether temperature can act as a limiting factor in the distribution of the species, the effect of the physical factor may, however, be of significance in their distribution. It has, for instance, been found by Vernon (1899) working with echinoid larvae and Andrews (1925) with *Thaumantia cellularia* that the lethal temperatures for the different larval stages showed differences. The lowest lethal temperatures being found in the case of the youngest developmental stages. If this holds good for molluscs, temperature may act as a limiting factor in the distribution of the veliger larvae or of slightly more advanced developmental stages of the snail and in that way may indirectly restrict the distribution of the mature individuals of several species.

A correlation is thus discernible between the temperature ranges of the intertidal zones, the temperatures lethal to mature individuals and the ability of these snails to resist prolonged high temperatures. The direct influence of temperature as a limiting factor in the vertical distribution of the mature snails is probably rather a limited one at least in the case of the species studied. In marine molluscs, in general, lethal temperature seems to increase with increasing height above low water level, while warm water forms on the whole show a higher lethal temperature than forms occurring in colder water. It has been pointed out that marine intertidal molluscs occupying different levels show variations in their tolerance to different temperatures (Gowenlock and Hayes, 1926; Gowenlock, 1926; Henderson, 1929).

Intertidal animals tend to tolerate wider ranges in salinity than do sub-tidal and open ocean organisms, and generally animals living in the upper intertidal zone area are
more tolerant of salinity fluctuations than are those in the lower intertidal zone. Tolerance to low salinities in intertidal zone animals has been linked to several mechanisms (Vernberg and Vernberg, 1972).

Salinity is a major physical factor in the intertidal habitat affecting the activities of organisms by influencing the density of the medium and through variations in the osmotic pressure. Panikkar (1950) discussed the physiological aspects of adaptations to estuarine conditions. Broekhuysen (1936) observed that salinity, oxygen and rate of sedimentation do not show variations in connection with the changes he noticed in the distribution of species. Salinity may affect directly the functional and structural properties of organisms and indirectly modifying the species composition of the ecosystem and consequently changing the biotic conditions prevailing in an ecological niche (Kinne, 1964). Effects of salinity on a non-sedentary organism will not be significant, since it can escape the stress by moving on to suitable conditions.

The influence of salinity on the distribution of marine animals has been investigated rather thoroughly by various investigators, and it is a well known fact that many marine animals have a salinity optimum at which they thrive best. Most of the work in this connection has been done on sublittoral pelagic and estuarine forms, but very little is known on marine tropical intertidal species (Dehnel, 1960; Doig, 1957; Oglesby, 1969). Salinity conditions in the intertidal zone during low water are seldom constant and may vary a great deal as a result of evaporation on sunny and windy days, and of dilution on rainy days. It, therefore, seems likely that in the case of intertidal forms it is rather the range of salinity which a species can withstand than the existence of a more or less constant salinity which affects the distribution, while in sublittoral and pelagic forms it has been found that the latter factor seems to be the more essential.

The results of salinity tests presented in Figs. 3a & b reveal that *N. leucosticta* can withstand a wide variation in salinity from 3.43 to 39.80%o. During low water, the individuals of this species are found in the highest zone, in rock pools as well as in a dry condition attached to the rock surface outside the pools. Those in the pools are subjected to great variations of salinity, as some of the smaller pools may lose all their water by

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**Fig. 3a.** Percentage mortality of *Littorina undulata* in different grades of salinity.  
**Fig. 3b.** Percentage mortality of *Nadilittorina leucosticta* in different grades of salinity.
evaporation before the next tidal wave reaches them. On rainy days the water of these pools is greatly diluted.

*L. undulata* can withstand a salinity range of 6.87 to 26.3°/oo. Although this species generally occurs rather low in the intertidal zone, most often it is noticed inhabiting pools. Being in close contact with the water of the pools, it is subjected to considerable variations in salinity, partly due to evaporation but chiefly on account of the dilution of water by rain. Those individuals of this species that occur at higher levels prefer exposed and bare rock surfaces, and some may even be found in the pools that occur high up in the intertidal zone.

The individuals of this species, therefore, must be able to withstand a certain degree of increase in salinity in the sense that some of the water retained within the shell is lost by desiccation during the exposure period and some of them as stated above do inhabit pools. On rainy days, however, most of the rain water runs down the rock surface without affecting the snails on the bare rock very much, since they are protected by their shells which adhere closely to the substratum. *Nodilittorina leucosticta* should thus show a better adaptation to variations in salinity than *Littorina undulata*.

**REFERENCES**


