ROLE OF CRITICAL TIDE FACTOR IN THE VERTICAL DISTRIBUTION OF *HYPNEA MUSCIFORMIS* (WULF.) LAMOUR

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Work on the ecology of intertidal marine algae in India is scanty and fragmentary. Most workers dealt largely with the general distribution pattern of the flora and its zonation. Much less attention has been paid to aspects of tidal rhythm and tidal range in determining the distribution pattern and zonation of algae.

In this paper an attempt has been made to draw out the significance of the critical tide factor in determining the vertical distribution of *Hypnea musciformis* (Wulf.) Lamour on Indian coasts.

INTRODUCTION

Studies on the ecology of marine algae in India are few (Parija and Parija 1946; Sreenivasan 1946; Krishnamurthy 1954, 1965; Prasannavarma 1959; Umamaheswara Rao and Sreeramulu 1964). Most of the authors have attempted to describe the pattern of zonation without correlating the factors that control the vertical distribution of intertidal algae. Umamaheswara Rao and Sreeramulu (1964) made an attempt to interpret the seasonal changes of the algal flora with the seasonal changes in the mean sea level but could not give any conclusive evidence to show the correlation between the tide factors and the vertical distribution of intertidal algae. Krishnamurthy (1965) had drawn attention to the causes of zonation and attributed the intertidal zonation to the interaction of many factors including the tide factor.

Setchell (1925) proposed that the exposure to wave action and sunlight are the principal factors in controlling vertical distribution of intertidal algae. Colman (1933) working at Wembury, Plymouth (England), was probably the first to stress the importance of tide levels in relation to the vertical distribution of marine algae. Later, Doty (1946) made a critical study of tide factors in relation to the vertical distribution of intertidal algae. Doty and Archer (1950) produced experimental evidence in support of this concept.

In this paper an attempt has been made to interpret the vertical distribution of the intertidal algae with special reference to *Hypnea musciformis* in relation to the existing tide factor at Veraval (Gujarat) on the west coast of India.

Tide phenomena of the place of investigation

Veraval is situated at lat. 20° 54′ N and long 70° 22′ E and has a rocky open reef with a gentle slope towards the sea. The entire reef is exposed during the intertidal period. The tides are of the mixed type and provide one of the factors whose variation is consistent throughout the region and which are correlated with the upward and downward migration of *Hypnea musciformis*. The climate offers another feature of ecological interest because a severe winter is followed by extremely hot summer. These two extremes play an important role in determining the vertical distribution of the intertidal algae. A study of the 1968 marigrams of Veraval (West coast of India) revealed a number of tidal phenomena that might be critical in governing the vertical distribution of the intertidal algae in general and *Hypnea musciformis* in particular. Fig. 1 illustrates a short section of the marigram for the period of June 1968. During this time of the year greatest difference between successive high-low and low-high waters, greatest difference between successive high or successive low waters and the greatest tide range occur. The maximum variation from the mean tide level occurs during the spring tide series and the minimum during the neap tide series. The tidal range is 7–8 ft above zero of chart datum. Fig. 2 illustrates the critical tide phenomena that may be recognised during such tide series.

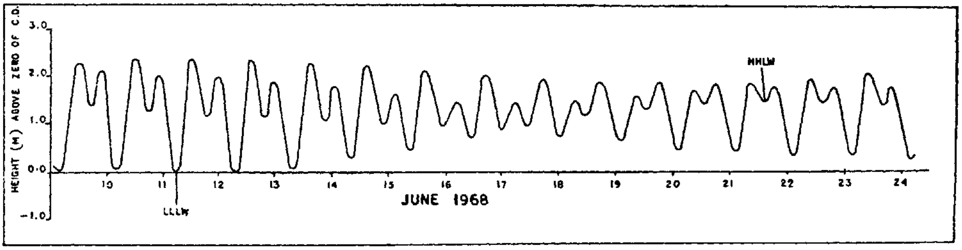

FIG. 1. A section of the marigram for June 1968 for Veraval, west coast of India, with days plotted along horizontal axis and the tide heights in meters above or below the chart datum plotted on vertical axis, illustrating, in particular, lowest lower low-water (LLLW) and highest higher low-water (HHLW) tide factors and regular gradual ; progression from one spring-tide to another spring-tide series through a neap tide series.

MATERIALS AND METHODS

An area which is plain without any tide-pools was selected near the mean low water mark and all the algae were cleared off. Percentage cover of *Hypnea* was estimated with the help of a 1×1 m wooden frame which is divided into 100 decimeter squares. Indian Tide-Tables' published yearly by the Survey of India were used for the preparation of tide charts, critical tide level charts and percentage emersion. The levels referred here are in meters with reference to zero of chart datum. Data on the mean monthly temperatures were obtained from the Regional Meteorological Centre, Colaba, Bombay-5.

RESULTS

Fig. 1 represents the section of marigram for June 1968 of Veraval and Fig. 2 indicates the various tidal phenomena that exist at Veraval. Fig. 3 represents the results obtained over a period of eighteen months for percentage cover of *Hypnea* drawn against the lowest lower low-water in each month and the upper limit of *Hypnea* in each month. It can be seen from the figure that there is a close correlation between the lowest low-water in each month and the upper limit of *Hypnea.* This upper limit varies along with the lowest lower low-water. It is a fact that LLLW

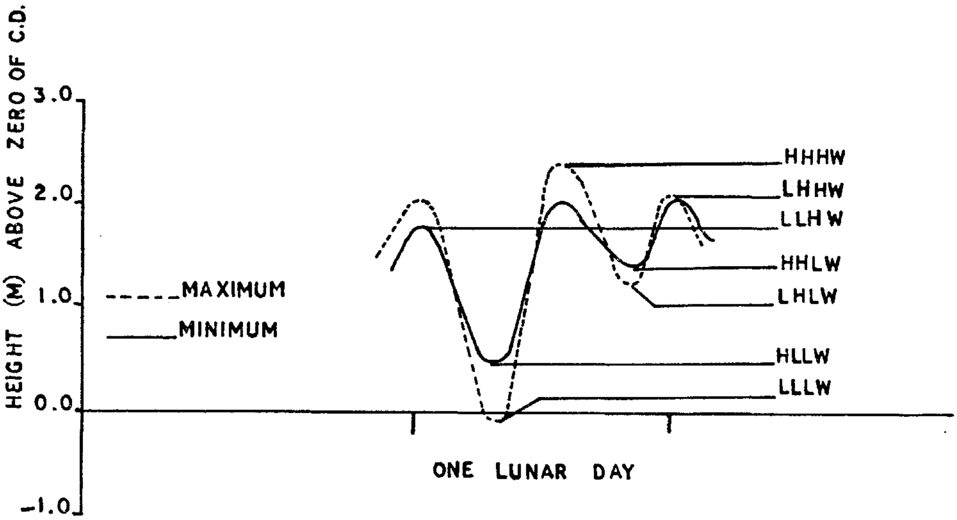

FIG. 2. Tidal variation during one lunar day.
(*HHHW*, Highest higher high water ; *LHHW*, lowest higher high water ; *LLHW*, lowest lower high water ; *HHLW*, highest higher low water ; *LHLW*, lowest higher low water ; *HLLW*, Highest lower low water; *LLLW*, lowest lower low water.)

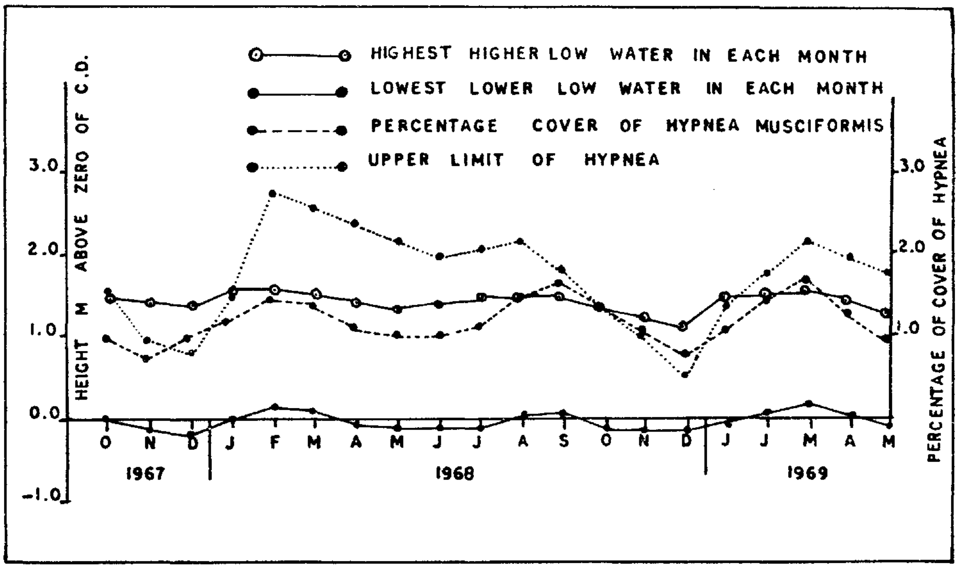

FIG. 3. Correlation of the vertical distribution of *Hypnea musciformis* and its percentage cover with the critical tide factors, lowest lower low-water and highest higher low-water operating at Veraval, West coast of India.

and HHLW operate as critical tide factors in determining the a upper limit of *Hypnea*. When the mean monthly temperature is plotted against the percentage emersion, interesting results are obtained. The lowest lower low-water occurred

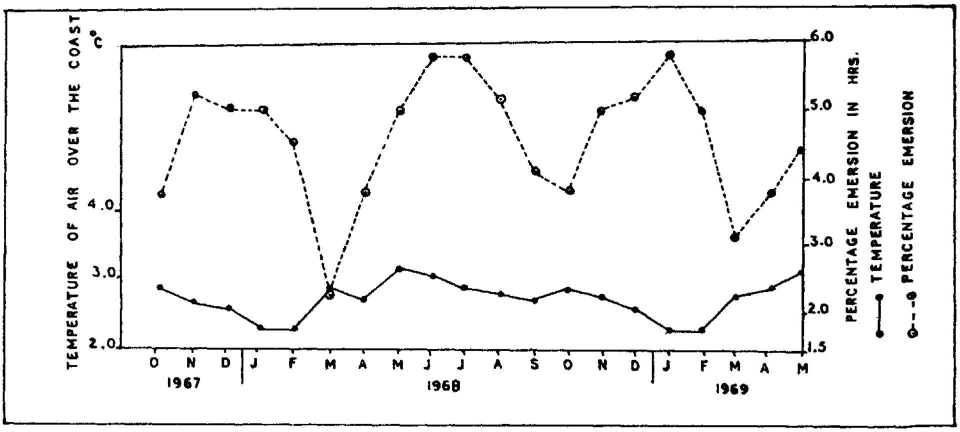

FIG. 4. The monthly variation of percentage emersion and temperature at Veraval.

from October to January and again from April to July. During these periods of the year the maximum emersion of the intertidal region takes place and hence the maximum percentage emersion results. Fig. 4 shows the mean monthly air temperature drawn against the percentage emersion. Air temperature is considerably high during those months when the percentage emersion is also maximum. Hence the percentage cover of *Hypnea* falls significantly to low values and the alga migrates to a lower region on the shore to protect against the desiccation due to higher temperature and insolation effects. This can be visualised from Figs. 3 and 4. Thus it is clear that the tide factors (here LLLW and HHLW) act as the primary factors in determining the vertical distribution of *Hypnea* while the percentage emersion and high temperature act as secondary factors. The visits to the coast during the summer months show a striking appearance with most of the algae of the subtidal fringe in a bleached condition. This indicates the effect of high temperature and insolation during summer months.

DISCUSSION

The importance of tidal changes in the zonation of marine algae has long been the subject for discussion. Grubb (1936) pointed out that the littoral algae grow best in that area of the shore where the conditions of emersion and submersion are those to which they are adapted. She pointed out that the direct effect of desiccation and certain other factors are important. Temperature and insolation can act as limiting factors, particularly for algae growing in the lower region of the shore. This can be seen from the present investigation which has demonstrated the downward migration of *Hypnea* due to the higher temperature and insolation during the period, April to July.

The literature relating to marine algae reveals a tendency to explain the vertical distribution of intertidal algae in terms of a single factor, usually illumination rather than to the combined effect of several factors such as temperature, substrate and wave action. Colman (1933) gave a new outlook when he estimated the degree of exposure integrated over a period of months for a number of algae at Wembury, Plymouth (England). Lawson (1956) stated that the type of zonation in all cases is to be related to the amount of exposure to wave action. This often depends upon the slope of the rock. The degree of exposure has a greater influence in determining the type of zonation occurring at any particular locality. He has also shown in his studies on the seasonal variation in vertical distribution of *Hypnea musciformis* for Ghana, West coast of Africa, how the tides, as a primary factor, play an important role. Womersley and Edmonds (1952) also stressed the existence of a critical level above LLLW. Doty (1957) emphasised that wave action may intensify zonation. Some of the latest attempts at correlation between percentage of total time of emersion or submersion and vertical distribution are those of Guiler (1951) in reference to zonation of the intertidal organisms in Tasmania. Dellow (1950) in a study of intertidal zonation near Auckland (New Zealand) Beveridge and Chapman (1950) and Carnahan (1952) likewise stressed the importance of total time of exposure and percentage of time exposed with elevation and explained what they termed as critical levels. Doty (1946) postulated that the critical tide factor regulated the exposure of organisms to the environmental variables, the tide factor being the primary factor. Later, Doty and Archer (1950) believed temperature to be an important variable in controlling the vertical distribution of intertidal algae. More recently Krishnamurthy (1969), in his studies on *Porphyra* at San Juan Island, Washington, pointed out that the climatic factors such as temperature and humidity and the time of emersion play an important role in restricting growth of *Porphyra* sp. at different levels.

At Veraval also, this type of effect can be seen. During winter months the percentage emersion is less when the temperature falls to the minimum. Hence, *Hypnea musciformis* extends to higher levels on the shore as desiccation due to exposure to high temperature is minimised. The conditions in summer months are just the opposite with the result the alga migrates to lower levels on the shore to overcome desiccation due to higher temperature and increased percentage emersion. A vertical migration of the belt of *Gracilaria-Grateloupea* on the Mahabalipuram coast near Madras was noticed by Srinivasan (1946) and this was again remarked upon by Krishnamurthy (1967). A similar vertical migration of the belt of *Hypnea musciformis* has been shown here on the Veraval coast. In this study the vertical migration of the alga has been related to LLLW and HHLW levels, thus establishing these as the critical tide factors for *Hypnea*.

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