Numerical Study of Intertidal Zonation along Visakhapatnam Coast, East Coast of India

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Quantitative data were collected for 1 year (Jan. to Dec. 1983) to study vertical distribution of plants and animals on intertidal rocky surfaces. Coefficients of community similarity and cluster analysis were used for studying the distribution of intertidal populations. Present data clearly showed the occurrence of 3 zones in the intertidal region of Visakhapatnam.

Intertidal zonation was studied in India from Visakhapatnam, Mandapam, Okha and Anjidiv Island. The zonation patterns and the classifications followed for describing zonation varied in the above areas. Russell applied numerical methods to study the distribution of populations and status of different zones present on intertidal rocky surfaces. Using these analytical methods, the present study was undertaken to examine the zonation of Visakhapatnam coast.

Materials and Methods

Visakhapatnam (17° 14'30" and 17° 45' N; 83° 16'25" and 83° 21'30" E) coast is sandy with outcrops of rocky boulders of various sizes and shapes. Quadrat samples were collected from 4 stations, selected previously, and from another station at Jodugullapalem, situated 4 km north of Visakhapatnam.

Algae and animals occurring at different vertical levels on the rocky surfaces were sampled at random using a quadrat (aluminium frame of 0.5 x 0.5 m in size). The number of algae and animals present in each quadrat was noted and cover values were estimated for as many species as possible. For estimating the cover, the quadrat frame was sub-divided with nylon thread into 25 sub quadrats and the cover data of the whole quadrat were expressed as percentage on a 5 point scale (1 = 0-20; 2 = 21-40; 3 = 41-60; 4 = 61-80; 5 = 81-100). A second quadrat sample was taken by placing the aluminium frame either to the right or left of the first quadrat as suggested by Russell. During the study period (Jan. to Dec. 1983) 144 quadrat samples were collected.

Species area curve was plotted using the formula

\[ (1 - \frac{n}{N})^q \]

where \( N \) = total number of quadrats, \( n \) = number of species present in the total number of quadrats, \( q \) = serial number of quadrats. The number of predicted species present in the quadrats increased rapidly from 2nd quadrat onwards up to 60th quadrat and there after remained constant indicating that a sample size 60 quadrats is necessary for obtaining maximum number of species in the area investigated.

Population similarity coefficients of Jaccard, Sorensen and Gleason were used to compare the quadrat samples collected from EHWS (2 m CD) to ELWS (-0.4 m CD) in the intertidal region. The first 2 coefficients are based on species presence data and the third one on the cover data. Mean values of duplicate samples were used for calculating the similarity coefficients. The \( t \) value (0.8055) calculated for the 2 sets of quadrat samples was less than the table value at 5% level (d.f. = 70) indicating that the difference between the duplicate samples is not significant. The values obtained for 72 quadrats were expressed as percentages in the similarity matrices.

Based on the species presence and absence data collected from 144 quadrats, cluster analysis was done. Species with a frequency of 5% or above were used in the cluster analysis. In this method degree of association or the index (represented by symbol \( I \)) between pairs of species was determined by \( \chi^2 \) analysis using the following formula:

\[ \chi^2 = \frac{(ad - bc)^2}{(a+b)(c+d)(a+c)(b+d)} \]

where \( n \) = total number of quadrats; \( a \) = presence of both A and B species; \( b \) = presence of only B species; \( c \) = presence of only A species; and \( d \) = absence of both A and B species.

These values of \( I \) are then entered in the association matrix to get different clusters of related communities.
Results

Relative frequency of 50 species obtained in the quadrats varied from 4.8% (Ceramium cruciatum) to 36.1% (Ulua fasciata). Data obtained on quadrat similarity are presented in Figs 1 to 3. In the similarity matrix based on coefficients of Sorensen$^{11}$, 3 different blocks can be seen (Fig. 1). Littorina undulata, Nodilittorina millegiana are the species of the upper shore block. Algae were not found in the quadrat samples of this upper shore block. The species observed in many quadrats of the middle shore block were: algae—Enteromorpha compressa, Chaetomorpha antennina, Porphyra viennamensis, Polysiphonia ferulacea, Acrochaetium iyengarii, Liagora erecta, Peyssonnelia conchicola; and animals—Chthamalus stellatus, Crassostrea grusphoides, Cellana radiata radiata, Nerita albicilla, Morula granulata, Balanus tintinabulum tintinabulum. The species observed in quadrats of the lower shore block were: algae—Cladophora utriculosa, C. socialis, Spongomorpha indica, Boodlea struveoides, Bryopsis pennata, Caulerpa fastigiata, C. racemosa, C. sertularioides, C. taxifolia, Dictyota dichotoma, Padina tetractomatica, Sargassum vulgare, Amphiroa fragilissima, Jania rubens, Grateloupia lithophila, Gelidiopsis variabilis, Gracilaria corticata, G. textori, Hypnea valentiae, Gigartina acicularis, Wrangelia argus, Aglaothamnion cordatum, Ceramium cruciatum, C. simbriatum, Bryocladia.

![Fig. 1 Similarity matrix of quadrat samples using Sorensen coefficient](image-url)
thwaitesii, Lyngbya majuscula; and animals—Electra pilosa, Stegmnoporella buskii, Stomopneustes sp. and Gemmaria sp. The quadrat samples of upper shore block showed complete dissimilarity with the remaining quadrats of middle and lower shore blocks. Similarly, the quadrats of middle shore block and lower shore block showed dissimilarity with remaining blocks, because of the differences in the species composition. These observations on the similarity between quadrats collected at different vertical levels indicate that 3 zones with sharp boundaries between them occur in the intertidal region of the Visakhapatnam coast. The similarity matrix based on Jaccard\textsuperscript{10} coefficient is shown in Fig. 2. As observed in Sorensen\textsuperscript{11} matrix, strong internal similarity was seen within the 3 blocks. The segregation of quadrat samples into 3 blocks or groups is very clear in Jaccard\textsuperscript{10} coefficient. Matrix based on Gleason\textsuperscript{12} coefficient is shown in Fig. 3. Clear-cut demarcation of the 3 zones can be seen in this matrix prepared from species cover data. But the similarity values within each block varied, depending on the cover data of each species and weightage given to it.

Overlapping was observed between the 3 different blocks (Figs 1 and 3). This may be due to sampling on irregular rocky boulders: downward and upward
movements of animals and also due to settlement of organisms depending on the differences in microhabitats. The similarity values obtained for the quadrats of overlapping populations were > 20% when Sorensen\textsuperscript{11} and Gleason\textsuperscript{12} coefficients were used (Figs 1 and 3). On the other hand with Jaccord\textsuperscript{10} coefficient the similarity values were < 20% and hence they were not depicted in the matrix (Fig. 2).

From cluster analysis (Fig. 4) 3 different groups have emerged from the populations of the intertidal region. Of the 50 species, recorded in 144 quadrats, 18 species had more than the predicted value at 0.001 probability (Fig. 4) and the 3 distinct clusters obtained in the present study clearly show the occurrence of 3 zones in the intertidal region of Visakhapatnam.

**Discussion**

At Visakhapatnam\textsuperscript{2}, the intertidal region is divided into 3 zones following the classification of Stephenson and Stephenson\textsuperscript{13}. The upper most supralittoral fringe extends from about 1.4 m CD to extreme high water springs (2 m CD). Algae were not found in this zone and it can be recognised by the presence of *Littorina* sp. The midlittoral zone is well defined with an average width of 1 m (0.4 to 1.4 m CD). There is a distinct barnacle line formed by *Chthamalus stellatus*.

![Fig. 3 - Similarity matrix of quadrat samples using Gleason coefficient (Similarity percentages as in Fig 1)](image-url)
Fig. 4—Cluster analysis based on highest $\chi^2$ values of species presence in 144 quadrats [Species: (a) 1 Litorta undulata, 2 Nodilittorina millegrana, (b) 3 Chthamalus stellatus, 4 Crassostrea graphoides, 7 Morula granulata, 10 Ulva fasciata, 11 Enteromorpha compressa, 12 Chaetomorpha antennina, and (c) 26 Spongomorpha indica, 27 Boodlea struveoides, 37 Wrangelia argus, 38 Gracilaria corticata, 41 Hypnea valentiae, 43 Amphirous fragilissima, 44 Jania rubens, 45 Chaetomorpha brachygona, 48 Stegmoporella huskii, 50 Gemmaria spp.]

that zonation pattern conformed with the classification proposed by Womersley and Edmonds$^{1,4}$. Umamaheswara Rao and Sreeramulu$^2$ didn't observe any subdivision and Ulva fasciata, Chaetomorpha antennina, Enteromorpha compressa, Porphyra viennamensis, Bangiopsis sub simplex, Chthamalus stellatus were found in the entire midlittoral zone from 0.4 to 1.4 CD as continuous bands. In the present study also total internal similarity (Figs 1 to 3) and positive correlation (Fig. 4) were observed between the quadrats sampled and populations of the midlittoral zone and dissimilarity and negative correlation were found between the quadrats and populations of midlittoral zone and infralittoral fringe (Figs 1 to 3). These findings on population similarity and cluster analysis further confirm the observations of Umamaheswara Rao and Sreeramulu$^2$.

Russell$^{7,8}$ used coefficients of Sorensen$^{11}$ and Gleason$^{12}$ in his quantitative work on zonation. In the present study in addition to Sorensen$^{11}$ and Gleason$^{12}$ coefficients, Jaccard$^{10}$ coefficient was also used for species presence data and it eliminated the small percentage of overlapping populations observed in some quadrats of the 3 zones. When compared with Sorensen and Gleason coefficients, Jaccard coefficient appears to be more suitable for the analysis of intertidal communities.

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