

The importance of the addition of electrolytes like, KCl,  $\text{NH}_4\text{Cl}$  and  $\text{KNO}_3$  has already been shown<sup>8</sup>. The gel strength can be increased by 5 to 15% with the addition of KCl (Table 1) which not only enhances gel strength but also controls gelation temperature (Table 1), as indicated earlier<sup>8</sup>.

From the present study, it seems that *Hypnea*, *Gracilaria*, *Gelidiella* and their mixtures can be used as a source of agar. However, to get the desired gel strength, KCl should be added before filtering the hot extract. But the addition of an electrolyte to increase the gel strength of the final product may not be desirable when agar is to be used for bacteriological investigations.

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### A Model for the Prediction of Zooplankton Abundance in an Estuary

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**Regression model for the prediction of zooplankton abundance correlating total numbers of zooplankton with salinity, temperature and oxygen from Cochin backwaters is presented. The variability explained by the parameters is 73.5% when the whole estuary is considered and 88.7% and 52.2% at 2 individual stations, viz. Aroor and Barmouth respectively. Salinity is the predominant factor controlling zooplankton abundance followed by oxygen and temperature.**

**ESTUARIES** are dynamic systems where environmental parameters and populations may change in magnitude over very short periods. Estuarine zooplankton, in addition to the true estuarine species comprise opportunist species, which blossom into brief blooms when conditions become ideal, euryhaline marine species and also accidental immigrants from both marine and limnetic regions.

A model for the prediction of zooplankton abundance using multiple regression is presented in the

present paper from 2 sets of data (i) monthly collections from Cochin to Alleppey during 1972 and (ii) monthly collections at 2 stations, viz. Barmouth (Cochin) and Aroor (about 14 km south of mouth) from Nov. 1971 to Oct. 1972. Zooplankton collections and measurements of the environmental parameters (salinity, temperature and oxygen) were made as reported earlier<sup>1,2</sup>.

Correlation coefficients were calculated between total numbers of zooplankton, salinity, temperature and oxygen. All the correlation coefficients being found significant, they were connected by a multiple regression model. The regression model fitted to the data was  $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ , where Y stands for total numbers,  $X_1$  for salinity,  $X_2$  for temperature and  $X_3$  for oxygen. The regression was fitted by the method of least squares and the normal equations were solved using matrix inversion. Significance of the regression coefficients was tested by analysis of variance and the relative importance of environmental parameters was estimated using

the formula:  $b_i \sqrt{\frac{\sum x_i^2}{\sum y^2}}$  (ref. 3).

The equation derived for the whole estuary (series 1) was  $\hat{Y} = -17.4733 - 0.0201X_1 + 0.8118X_2 - 1.2685X_3$ . It was  $\hat{Y} = 4.1574 + 0.0643X_1 - 0.0438X_2 - 0.2801X_3$  at Aroor and  $\hat{Y} = 5.4335 + 0.0559X_1 - 0.1532X_2 + 0.2877X_3$  at Barmouth.

The test of significance for regression coefficients (Table 1) showed that in series 1 and at Aroor, the fitted regressions were highly significant ( $P < 0.001$ ) while at Barmouth it was significant at a lesser level ( $P < 0.05$ ). The variability explained by the fitted regression was 73.5% in series 1, 88.7% at Aroor and 52.2% at Barmouth.

Proximity to the mouth results in an early recovery of salinity after the monsoon season enhancing a longer duration of typical estuarine conditions at Aroor. During the monsoonal period salinity and zooplankton population are very low at this station. Hence the parameters considered accounted a higher percentage of variability at Aroor. But Barmouth is subjected to greater turbulence even during premonsoon period resulting in greater variations in environmental parameters and fauna. During the monsoonal period also the salinity values ranged from near zero values during low tide to 35.5‰ at the bottom during high tide. This indicates that other factors such as turbidity, currents and tidal dispersion, food, extent of pollution, etc. may have to be considered to explain the total variability occurring in the environment. Organisation of communities is influenced by multiple environmental stresses and organisms increase or decrease in response to these.

Relative importance of the 3 parameters in the equation are given in Table 2. In all cases salinity is the most prominent factor controlling zooplankton abundance followed by oxygen and temperature. Being a tropical estuary, fluctuations in temperature are of low magnitude to affect the organisms drastically. But sharp variations in salinity occur in the estuary and zooplankton population is very low

TABLE 1 — ANALYSIS OF VARIANCE FOR TESTING SIGNIFICANCE OF REGRESSION

	Series 1				Aroor				Barmouth			
	SS	DF	MS	F	SS	DF	MS	F	SS	DF	MS	F
Regression	74	3	24.66	77.79 <sup>c</sup>	8.35	3	2.78	29.75 <sup>c</sup>	2.8	3	0.93	5.01 <sup>a</sup>
Deviations	25.36	80	0.31		0.74	8	0.09		1.49	8	0.19	
Total	99.37	83	1.19		9.1	11	0.83		4.29	11	0.39	

a,  $P < 0.05$ ; c,  $P < 0.001$ .

TABLE 2 — RELATIVE IMPORTANCE OF PARAMETERS IN THE REGRESSION MODEL

	Series 1	Aroor	Barmouth
Salinity	2.0596	0.7758	0.8507
Temperature	0.5254	0.0742	0.2874
Oxygen	0.7779	0.2998	0.3515

during the low saline monsoon period. The abundance of copepods in the estuary has been found to be significantly correlated with salinity<sup>4</sup>. Similar results have been obtained for zooplankton by Pillai *et al.*<sup>5</sup>.

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**Bioaccumulation of Iron in *Anadara rhombea* (Born) (Bivalvia: Arcidae)**

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Iron content of the mantle, ctenidia, adductor muscle, digestive gland and foot of *A. rhombea*, collected from 2 localities with different sedimentary iron concentrations was estimated. Iron content of tissues was found to be an indicator of the environmental iron concentration. During starvation iron content in all the body organs decreased, and steep decline was noted in digestive gland and ctenidia, the chief organs associated with digestion and feeding which normally show higher concentration of iron.

AMONG bivalves, members of the family Arcidae contain haemoglobin (iron compound) in their blood<sup>1</sup>. Many workers have reported trace elements uptake, their effect on the animals and the concentration factor between the organism and the environment<sup>2,4</sup>. Previous studies show that in

estuarine systems concentration of these trace elements is higher in sediments, especially muddy sediments<sup>5,8</sup>. In shallow estuaries, the large amount of suspended particles present are filtered by the bivalves, the feeding of which chiefly depends on the particle size of the food material present. Silt and other light sediment particles form most of the suspended matter in the overlying waters of muddy sub-tidal areas. The trace elements present in the sediments thus find their way into the bivalve body.

An attempt has been made to study the flux of iron from the sediment to various body organs of the mud living estuarine arcid bivalve *Anadara rhombea* (Born), from 2 localities. Concentration of exchangeable or biologically reactive fraction of iron in the sediment and the effect of starvation on the bioaccumulated iron have also been studied.

Specimens of *A. rhombea* (Born) were collected from 2 localities, the mudflat which extends from the Pitchavaram mangrove up to the seaward outlet of Killai backwaters at Chinmavaikkal (11°26'N; 79°48'E) and the muddy area in the tidal zone of Vellar estuary (11°29'N; 79°46'E). The specimens, ranging from 4 to 5 cm in length, were all with gonads in the spent stage. Animals were kept in filtered seawater for one day, to clear the digestive tract. Mantle, ctenidia, adductor muscle, digestive gland and foot (including the gonad and the body wall) were isolated, washed with distilled water and dried at 70°C in an oven. Tissues were always kept out of contact with iron instruments or particles. These tissues were digested with perchloric acid and the iron content was estimated following the method described by Stickland and Parsons<sup>9</sup>.

Another sample of animals from the estuary was kept in filtered seawater for 6 days before tissues were analysed for iron content.

Surface sediments (5 cm depth) were taken from different areas of mangrove mudflat and the estuary, dried and the iron was extracted with 0.1N HCl and estimated following the procedures of Cross *et al.*<sup>2</sup>. Iron thus estimated in the sediment provided a gross measure of the fraction of iron available for exchange between sediment and biota.

Biologically reactive iron at the 2 localities differed markedly. In the mangrove sediment the values were higher ranging from 3115.78 to 3330.22 µg/g while in the estuarine sediment it ranged from 1635.47 to 1663.05 µg/g.

Amount of iron in the body of the clams varied significantly in both the biotopes (Fig. 1). Maximum iron content with respect to dry weight was in foot followed by adductor muscle, mantle ctenidia and digestive gland. Values were higher in all the