

PREDICTION EFFICIENCY OF THE HYDROGRAPHICAL PARAMETERS AS RELATED TO DISTRIBUTION PATTERNS OF THE PLEUROMAMMA SPECIES IN THE INDIAN OCEAN

K. V. JAYALAKSHMY AND M. SARASWATHY

National Institute of Oceanography, Regional Centre, Cochin - 682 018, India

ABSTRACT

Among species of the genus *Pleuromamma*, *Pleuromamma indica* was the only species existing in the northern Indian Ocean. In the rest of the Indian Ocean the most abundant species was *P. gracilis*, and *P. abdominalis* was almost homogeneously distributed. Multiple regression model of *P. indica* abundance on the parameters: temperature, salinity, dissolved oxygen and phosphate - phosphorous could explain more than 85% of the variation in the predicted abundance, while those of 8 species obtained from the equatorial region and southern coast off South Africa could explain only 30% of the variations in the predicted total abundance and it was attained only when average values of the parameters were considered in both cases. Hence average values of the parameters were the optimal values of the parameters to be considered for maximum information about the distribution of *Pleuromamma* species. High diversity and low dominance (high evenness) were observed in the distribution of *Pleuromamma* species in the equatorial region.

INTRODUCTION

Study of the Calanoid copepod *Pleuromamma* in the upper 200 m water column in the Indian Ocean has resulted in certain interesting observations (Saraswathy, 1986, and Saraswathy and Krishna Iyer, 1986) such as the dominance of *P. indica* in northern most region of the Indian Ocean where waters are characterised by high productivity and a strong oxygen minimum, and occurrence of *P. quadrangulata* only in the restricted area of the equatorial belt, in the upper 200 m depth of the water column. The area of investigation in this study which includes (1) Arabian Sea (2) Bay of Bengal in the north and (3) water of southern Indian Ocean in the south, present a most variable environment and the species of genus *Pleuromamma* are known to exhibit pronounced diurnal vertical migration, being very sparsely distributed or almost absent in the upper 200 m during day.

MATERIALS AND METHODS

The region of study consists of Bay of Bengal (10 stations), Arabian Sea (7 stations) (Fig. 1) equatorial region (13 stations) and southern Indian Ocean off South Africa (4 stations). The specimens were collected from the upper 200 m water column during the International Indian Ocean Expedition (IIOE) using the Indian Ocean Standard Net. Both day and night collections were taken. Data on the different parameters were obtained from data sheets from World Data Centre. *P. indica* was present only in the first three regions. In the third and fourth regions, 8 and 6 species respectively were present and these data were pooled based on the similarity with respect to number of common species in the two regions, using the similarity index, $A = \frac{c \times 100}{a - c}$ where c = number of species common to both regions and a = total number of species in both regions and $A = 75\%$ for the

third and fourth regions, and therefore the third and fourth regions are pooled together for the study of the distribution of all the 8 *Pleuromamma* species which are present only in 3rd and 4th regions. Eight species considered were (1) *P. abdominalis* (PA), (2) *P. xiphias* (PX), (3) *P. quadrangulata* (PQ), (4) *P. indica* (PI), (5) *P. gracilis* (PG), (6) *P. piseki* (PP), (7) *P. borealis* (PB) and (8) *P. abdominalis abyssalis* (PAA).

In order to find the prediction efficiency of the hydrographical parameters considered at four different levels viz. surface, maximum, minimum and average values, where the average calculated is the simple arithmetic mean of the values of the different parameters given for various depths in the 200 m water column considered separately, in predicting the abundance of the species, data after logarithmic transformation (Colebrook, 1960), $\underline{Y} = \log_{10} (X+1)$, X = original value, \underline{Y} = transformed value, was subjected to regression analysis (Snedecor and Cochran, 1963). The variability explained by the regression equations and relative importance of the parameters in the case of significant regression equations (Snedecor and Cochran, 1963) were also calculated. To study the coexistence of different species over space an interspecies coefficient of correlation matrix was formed. Cluster analysis (Sanders, 1978) was carried out using the correlation matrix for combining the species at various similarity levels and the dendrogram showing the grouping at different similarity levels were drawn (Fig. 2). Coefficient of correlation of each species with parameters at each level was also calculated. Richness coefficient and evenness in the species distribution was calculated using Shannon Wiener diversity function (Lloyd and Ghelardi, 1964) $\underline{H}(\underline{s})$ and Mac Arthur's coefficient of equitability $\underline{\Sigma}$ respectively.

$\underline{H}(\underline{s})$ and $\underline{\Sigma}$ were plotted against latitude to study nature of distribution of $\underline{H}(\underline{s})$ and $\underline{\Sigma}$ with respect to latitude (Fig. 3).

RESULTS AND DISCUSSION

In the upper 200 m water column, temperature variation in the area was between 30.52° C in the north east Arabian Sea and 10.37° C off Australia. Salinity varied between 37.36x10⁻³ in the north Arabian Sea and 32.10x10⁻³ in the central Bay of Bengal. Dissolved oxygen varied from 5.79 ml/l off South Africa to 0.1 ml/l in the Arabian Sea and Bay of Bengal. Phosphate values ranged between 2.43 µg at/l in the north Arabian Sea and almost nil at some stations south of 20°S. Only at one station, dissolved oxygen values varied between 0.1 ml/l and 5 ml/l at different depths.

Most abundant species was PG (G. M. = 64.6/haul) and least abundant was PQ (G. M. = 2/haul). PA had the least scattered distribution (C. V. = 22.6%) while PQ had the most scattered distribution (C. V. = 156.8%). Correlation coefficient of PX, PI, PP and PB with temperature, of PA with salinity and of PI, PB with dissolved oxygen and PI with phosphate - phosphorous were significant at 5% level of significance at all levels, ($P < .05$) (Table 1) except PX, PI and PB with temperature at minimum level. Thus it implies that in the equatorial region and the southern Indian Ocean off South Africa, high temperature is favourable to PX, PI and PP while not to PB. High salinity is preferable to PA, high dissolved oxygen is not preferable to PI, but is preferable to PB and high phosphate phosphorous is preferable to PQ and PI while not to PB. In the case of PG and PAA the considered parameters are neutral in their effects to control their abundance which suggests that some other factors, not considered in the present study are to be

HYDROGRAPHY FOR PREDICTION OF COPEPOD SPECIES

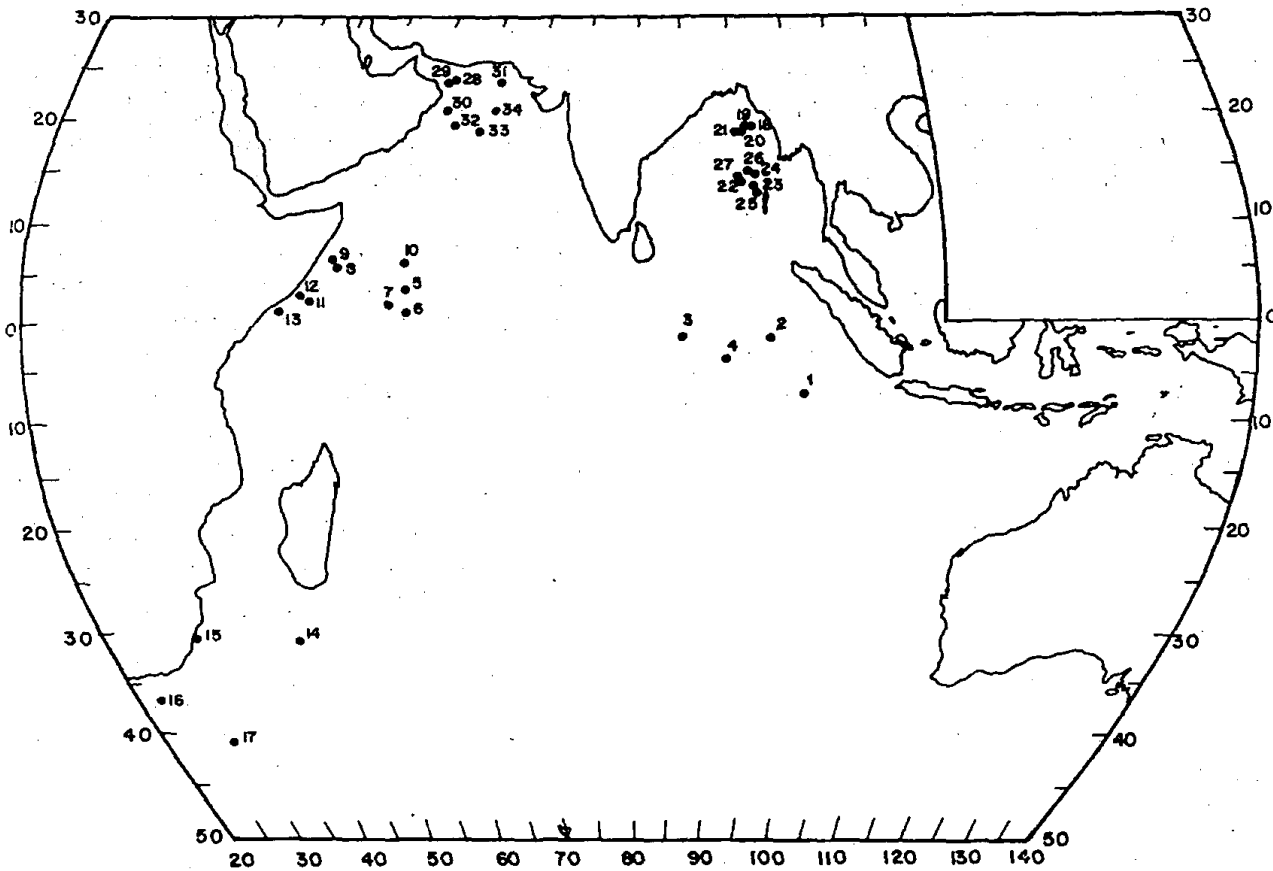


Fig. 1. The station locations in the 4 regions, Arabian Sea, Bay of Bengal, equatorial region and southern Indian Ocean off South Africa, selected for the study.

given due importance (Table 1). These suggestions have been justified from prediction equations also. Multiple regression equation of PI abundance on parameters, using (a) maximum value of the parameters was

$$\bar{Y} = -71.2422 + 4.8939 X_1 + 37.8302 X_2 + 6.8335 X_3 + 4.4479 X_4$$

(b) Minimum value of parameters, was

$$\bar{Y} = -14.6880 + 4.3236 X_1 + 10.3801 X_2 - 3.6541 X_3 + 2.5675 X_4$$

(c) Surface value of the parameters, was

$$\bar{Y} = 29.1796 + 12.8298 X_1 + 1.1401 X_2 + 14.2916 X_3$$

$$+ 1.9363 X_4$$

(d) Using average value of the parameters, was

$$\bar{Y} = -17.5896 + 3.2548 X_1 + 9.9485 X_2 - 2.7922 X_3 + 5.1408 X_4$$

All the 4 regression equations were highly significant at 1% level ($P < .01$). Variability explained by the regression models were all $> 60\%$ in all cases. Maximum variability was explained by the regression model (d) i. e. 85.83%. ($F(4,25,1\%) = 43.9224$), then 78.43%, by (a) and (b) ($F(4,25,1\%) = 26.7345$) (Table 2). This therefore clearly shows that the average values of the parameters can extract the maximum information about the

distribution of *PI* in the three regions considered. Multiple regression equations fitted for the total abundance of all the 8 species based on the pooled data, using,

(a) Maximum value of the parameters, was

$$Y = -25.3195 + 0.8506X_1 + 14.2856X_2 + 6.0550X_3 - 0.5485X_4$$

(b) Minimum value of the parameters, was

$$Y = 50.8706 + 3.5499X_1 - 34.4663X_2 + 1.8762X_3 + 1.5307X_4$$

(c) Surface value of the parameters, was

$$Y = -34.1922 - 2.3143X_1 + 28.8275X_2 - 6.1909X_3 - 1.0231X_4$$

(d) Average value of the parameters, was

$$Y = 6.0326 + 1.6990X_1 - 6.9983X_2 + 6.6833X_3 + 3.2027X_4$$

Where Y = total species abundance, X_1 = temperature, X_2 = salinity, X_3 = dissolved oxygen, X_4 = PO_4 -P.

Above equations used for prediction were significant only at 25% level of significance ($P < 0.25$) when maximum ($F(4,12,25\%) = 2.1619$) and minimum ($F(4,12,25\%) = 1.5657$) values were taken, while at 10% level of significance when average values of the ($F(4,12,10\%) = 2.2913$) ($P < 0.10$) parameters were taken. But it was not significant when surface values were used. Therefore, for the prediction of total abundance of all 8 species also, average values are the optimum values of the parameters and gives the relatively maximum precision. Also regression analysis confirms that these parameters alone are not sufficient because it can explain only 30.9% (Table 2) of the variability in the predicted total abundance. *PG* the most abundant species was not found to be highly correlated with any of the 4 parameters

considered. That is *PG* may be depending on factors such as water turbidity, light penetration, nutrients or interaction effects of these parameters (Table 3) which are significantly correlated. PO_4 -P was the relatively most important factor when maximum values were used, dissolved oxygen, when minimum values were used, temperature when surface values were used, and PO_4 -P when average values were used for predicting abundance of *PI* alone while dissolved oxygen in the case of maximum and minimum values, temperature when surface values and PO_4 -P when average values were considered for predicting the total abundance of all 8 *Pleuromamma* species from the two pooled regions (Table 2).

From Dendrogram, cluster having maximum affinity at 5% level was (*PA*, *PP*,

DENDROGRAM

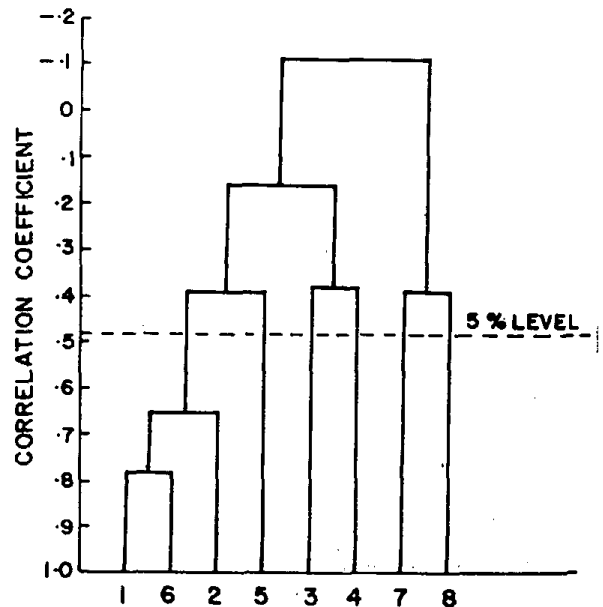


Fig. 2. The significant clusters formed at 5% level of significance. The numbers on the X-axis represent species as follows; 1. *Pleuromamma abdominalis*, 2. *P. xipias*, 3. *P. quadrangulate*, 4. *P. indica*, 5. *P. gracilis*, 6. *P. piseki*, 7. *P. borealis* and 8. *P. abdominalis abyssalis*.

HYDROGRAPHY FOR PREDICTION OF COPEPOD SPECIES

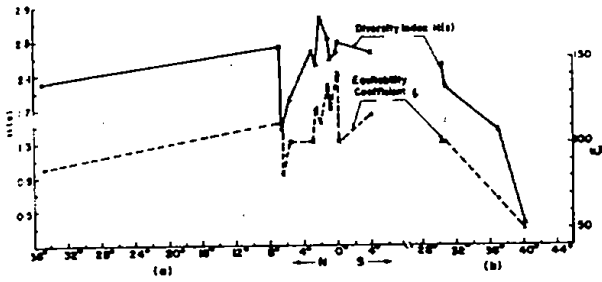


Fig.3. The diversity index $H(s)$ and equitability coefficient with respect to latitude.

PX). This group coexists with a minimum correlation of 0.65 (Fig. 2).

$H(s)$ was almost uniform \bar{X} of $H(s) = 2.2399$ in the equatorial region except at stations, at $5^{\circ}40'N$ $51^{\circ}41'E$ and $6^{\circ}34'N$ $51^{\circ}E$ while not uniform in the southern coast of South Africa. Maximum Σ in equatorial region was at $0^{\circ}2'S$ $93^{\circ}0'E$ and $0^{\circ}2'S$, $84^{\circ}56'E$ minimum at $06^{\circ}34'N$ $51^{\circ}00E$ while maximum Σ at southern coast of South Africa was at $30^{\circ}57'S$ $43^{\circ}11'E$ and $30^{\circ}20'S$ $31^{\circ}57'E$ and minimum at $40^{\circ}02'S$ $29^{\circ}29'E$ (Table 4).

Pleuromamma species are more evenly distributed in equatorial region than at southern coast of South Africa. There is a general trend of increase in $H(s)$ as well as Σ in equatorial region while a steady decrease in both $H(s)$ and Σ was noticed with latitude off South Africa (Fig. 3). Spatial distribution of the species in the stations taken for the study had indicated certain environmental preferences such as isolation of *P. indica* in the northern- most area, presence of *P. quadrangulata* in the equatorial region only and of *P. borealis* almost entirely in the southern most areas and in the east coast of Africa. Low dissolved oxygen, and high phosphate phosphorous for *PI* while high salinity for *PA* are highly favourable conditions. *PA*, *PP* and *PX* form a highly coexisting group. In order to get maximum information about the *Pleuromamma* species, average values of the

TABLE 1. The significant correlations of species with the parameters

Species	Maximum values			Minimum values			Surface values			Average values		
	Temp.	Sali.	Di. oxy.	Temp.	Sali.	Di. oxy.	Temp.	Sali.	Di. oxy.	Temp.	Sali.	Di. oxy.
P.A.	.5228			.5656	.5629		.5053			.5736		
P.X.	.5542						.5785			.5994		
PQ.			.4825									
P.I.	.7813	-.6728	.8506			-.6664	.5085	.7782	-.7105	.5202	.7380	.7825
P.G.												
P.P.	.4909							.5278			.5958	
P.B.	-.5417		.5019			.6464		-.5405				.5047
P.A.A.												

HYDROGRAPHY FOR PREDICTION OF COPEPOD SPECIES

parameters highly correlated with the species are to be considered.

ACKNOWLEDGEMENTS

The authors thank the Director, NIO, Goa, for facilities and Dr. M. Krishnan Kutty and Dr. T. S. S. Rao for the interest in this work. One of the authors (MS) is grateful to UNESCO for providing a travel grant which gave the opportunity to examine the plankton samples of R. V. Anton Bruun from waters in the Indian Ocean.

REFERENCES

COLEBROOK, J. M. 1960. Continuous plankton recorder methods of analysis, 1950, 1960. *Bulletin of Marine Ecology*, 5 : 51 - 64.

HOWARD, L. SANDERS 1978. Florida oil spill impact on the Buzzards Bay benthic fauna, West Falmouth. *J. Fish. Res. Bd. Can.* 35 : 717 - 730.

LLOYD, B. AND R. J. GHELARDI 1964. A table for calculating the equitability component of species diversity. *J. Anim. Ecol.*, 33 : 1 - 3.

SARASWATHY, M. 1986. *Pleuromamma* (Copepoda - Calanoida) in the Indian Ocean *Mahasagar: Bull. Natn. Inst. Oceanogr.* 19 (3) : 185 - 201.

SARASWATHY, M. AND H. KRISHNA IYER 1986. Ecology of *Pleuromamma indica* Wolfenden (Copepoda - Calanoida) in the Indian Ocean. *Indian J. mar. Sci.*, 15 (3) : 219 - 222.

SNEDECOR, G. W. AND W. G. COCHRAN 1963. *Statistical Methods*. Oxford & IBH Publishing Co. (6th Edition) : 582 pp.