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THE APPLICATION OF VARIANCE ANALYSIS FOR THE COMPARISON OF SPATIOTEMPORAL VARIATION IN FRESHWATER ZOOPLANKTON

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ABSTRACT

The spatial and temporal variations of zooplankton community of an artificial lake of Calcutta have been analysed by integrating the two factors. Component of variances associated with station, date, station-date interaction and error were worked out using 2-way analysis of variance. The station component yielded information on fixed horizontal spatial variation, the date component measured the variations in abundance through time, the interaction components were associated with ephemeral spatial patchiness which changed character through time. There were marked differences in relative importance of spatial and temporal variations of cladocera and copepoda. The ephemeral spatial variations were greater than fixed spatial variation in all species and their stages. However it was more important to cladocera than copepoda. In cladocera the spatial component of variance (fixed+ephemeral) also exceeded the temporal component of variance but it was reverse in case of copepoda.

INTRODUCTION

While there are a large number of published works dealing with variations in zooplankton populations in space and time, including some of those involving highly advanced and sofisticated sampling and analysis techniques, very few workers have attempted to integrate the two factors in order to obtain a composite and interdependent picture. With the result, the vast amount of available literature could not provide any definite understanding of the relationship between the two, particularly their relative magnitude. Margalef (1958, 1967) made first attempt to integrate the two variations and recently Lewis (1978) suggested the use of variance components for the analysis of spatio-temporal variation in zooplankton. The objectives of this paper are to integrate and compare the two factors in the crustacean zooplankton community of an artificial lake, Rabindra Sarovar (Dhakuria lake) of Calcutta by variance analysis as suggested by Lewis (1978) and to check the efficiency of the method.

MATERIALS AND METHOD

The present report is based on the data collected during detailed studies on the population and production ecology zooplankton in Ravindra Sarovar, where samples have been collected regularly since 1975 to date. Rabindra Sarovar is an artificial lake constructed by Calcutta Improvement Trust mainly for recreational purpose. The main lake, which is elongated in shape, covers an approximate area of 72 acres. The maximum length is 1770 meters, while the width at the broadest point is 282 meters. Mean depth varies from

9.3 meters to 10.5 meters. It is mainly fed by rain water.

Since spatial variation studies require the sampling of the entire limnetic zone throughout the lake and sampling stations should not be strongly correlated with their biological similarity ; 5 different stations, situaten at suitable distances spread over the entire lake, were selected (Fig. 1). The prerequisite for temporal studies as reported by Lewis (1978), is that the samples should be far enough aprart in time that they are not autocorrelated. For this samples of 7 different dates, covering the entire year, were taken into consideration. These sampling dates are January 15, March 20, May 5, June 16, August 25, October 15 and November 30 of 1977.

fixed in 4% formalin and brought to the laboratory where identification, classification and enumeration were done simultaneously under a binocular of varrying magnification. Only crustacean zooplankton have been taken into consideration. Copepods were divided into 4 classes, nauplii, copepodites, adults and eggs and cladocerans were divided into 3 classes, juveniles, adults and eggs-neonats. The details of classification have already been described (Khan 1981).

Statistical Analysis

An ordinary 2-way analysis of variance has been carried out taking station and date factors, for each class, following Mather (1964) and Sum of Squares and Mean Squares

Fig. 1. Outline of Rabindra Sarovar showing the possition of sampling station.

Duplicate samples were collected at each station on each date with the help of water sampler from different depth covering the entire column. One litre of water was collected from 5 to 6m depths at each station starting from the bottom to the surface and filtered through a No. 25 bolting nylon plankton net. Since the samples of all depth at any station were pooled, the term spatial variation represents the spatial variation in abundance beneath an unit of lake surface and comprised only horizontal distribution, not the vertical. Zooplankton samples were

for total, station, date, station-date interaction and error were worked out. From the Mean Squares, the components of variance were computed as follows, following Lewis (1978).

$$Se^2 = MSe$$
$$Ss^2 = (MSs - MSi)/Nd.\ Nr$$
$$Sd^2 = (MSd - MSi)/Ns.\ Nr$$
$$Si^2 = (MSi - MSe)/Nr$$

Where S^2 = variance, MS = mean square, N = number of samples, e = error, S = station, d = dates, i = interation and r = replicates. Each

TABLE 1. Components of Variance and Variance ratios for Different species of Zooplankton

Code Nos.	Species stages	Percent of variance				Ratio		
		Station (Ss^2)	Date (Sd^2)	Station date interaction (Si^2)	error (Se^2)	$Ss^2.Sd^2$	$Si^2.Sd^2$	$\frac{Ss^2+Si^2}{Sd^2}$
	Haliodiaptomus contortus							
1	Nauplii	10	75	11	4	0.130	0.146	0.280
2	Copepodite	8	60	20	12	0.130	0.133	0.466
3	Adult	10	72	12	6	0.140	0.166	0.305
4	Egg	13	50	22	15	0.260	0.440	0.700
	Themacyclops hyalinus							
5	Nauplii	13	62	19	6	0.216	0.306	0.516
6	Copepodite	6	80	10	4	0.075	0.125	0.200
7	Adult	20	55	21	3	0.363	0.400	0.763
8	Egg	28	36	30	6	0.777	0.833	1.611
	Mesocyclops leuckarti							
9	Nauplii	6	55	22	17	0.109	0.400	0.509
10	Copepodite	8	62	25	5	0.126	0.403	0.532
11	Adult	8	48	30	14	0.166	0.625	0.792
12	Egg	10	56	22	12	0.178	0.393	0.571
	Microcyclops varicans							
13	Nauplii	10	50	28	12	0.200	0.560	0.760
14	Copepodite	20	50	13	7	0.400	0.260	0.660
15	Adult	15	40	30	15	0.375	0.750	1.125
16	Egg	10	50	28	12	0.200	0.560	0.760
	Ceriodaphnia cornuta							
17	Juvenile	20	35	38	7	0.571	1.085	1.657
18	Adult	31	30	33	6	1.033	1.100	2.133
19	Egg/Neonate	28	20	35	17	1.400	1.750	3.150
	Daphnia carinata							
20	Juvenile	30	20	42	8	1.500	2.100	3.600
21	Adult	30	25	35	10	1.200	1.400	2.600
22	Egg/Neonate	25	35	38	2	0.714	1.080	1.800
	Moina micrura							
23	juvenile	35	20	40	5	1.750	1.000	3.750
24	Adult	25	20	52	3	1.200	2.080	3.250
25	Egg/Neonate	35	20	35	10	1.150	1.750	3.500
	Bosmina longirostris							
26	juvenile	30	26	35	9	1.153	1.340	2.500
27	Adult	29	20	36	15	1.400	1.800	3.250
28	Egg/Neonate	32	29	35	4	1.103	1.200	2.310

component was expressed as percentage of total variance. The ratios between station components and date components (Ss^2. Sd^2), between interaction component (Si^2. Sd^2) and composite ratio (Ss^2+Si^5)/Sd^2 were worked out.

The station component (Ss^2) is associated with variations between stations independant of date and represents fixed spatial patchiness. The date component (Sd^2) is a measure of variations in abundance through time. The interaction component (Si^2) is related to zooplankton patchiness which changes its formation everytime and has been termed as ephemeral spatial patchiness. The ratio Ss^2. Sd^2 measures fixed spatial patchiness against time variation while the ratio Si^2. Sd^2 measures ephemeral spatial variance against time variations. The composite ratio (Ss^2+ Si^2)/Sd^2 compares the sum of both types of horizontal spatial variations with temporal variations.

Results and Discussion

The crustacean zooplankton of Rabindra Sarovar were mainly composed of one calanoid, *Haliodiaptomus contortus* (Gurney), 3 cyclopoid, *Thermocyclops hyalinus* (Rehberg), *Mesocyclops leuckarti* (Claus) and *Micrcyclops varicans* (Sars) and 4 cladocerans, *Ceriodaphnia cornuta* Sars, *Daphia carinata* King, *Moina micrura* Kurz and *Bosmina longirostris* (O. F. Muller). The components of variance expressed in terms of percentage alongwith the ratios for each group are given in Table 1. It is apparent that while station component in all stages of calanoids and cyclopoid was never large enough showing low contribution of variance related to fixed horizontal spatial patchiness, in all cladocerans this component formed sizeable percentage and was mostly higher than date component revealing somewhat higher variances in fixed spatial patchiness. However, in no case the station component overtook the interaction component revealing the greater importance of ephemeral spatial variation. The ratios Si^2. Sd^2 were always less than 1 in copepods but more than 1 in cladocerans (except in juveniles of *Ceriodaphnia cornuta*), showing that fixed spatial variation exceeded temporal variations in cladocerans. The ratio Si.^{2}Sd^2 also revealed almost similar results, where ephemeral spatial variations exceeded the size of temporal variations in cladocerans. The relative importance of total spatial and total temporal vaviations is exhibited by the composite ratio (Ss^2+Si^2)/Sd^2, which was again high in case of cladoceran and always exceeded 1.5. Among copepods only eggs of *Thermocyclops hyalinus* exhibited a ratio more than 1. For all other copepod stages, temporal variation and total horizontal variation were of almost equal importance. These phenomena have become more clear when the ratio Si^2/Sd^2 was plotted against the ratio Si^2/Sd^2 (Fig. 2). It shows the low relative magnitude of fixed spatial variance, where none of the species fell in the category of fixed Ephemeral. Lewis (1978) pointed out that fixed spatial variance is greater in lakes with point source of heterogeneity such as effluents or tidal input or situations where both limnetic and littoral habitats have been sampled. Since samples from Ravindra Sarovar were collected quite away from littoral region and there was no intake way near any of the stations, the low importance of fixed spatial variance is quite expected. This also reveals that the limnetic zone of the lake is almost homogeneous.

The two groups of crustacean zooplankton, the copepoda and cladocera differ considera-

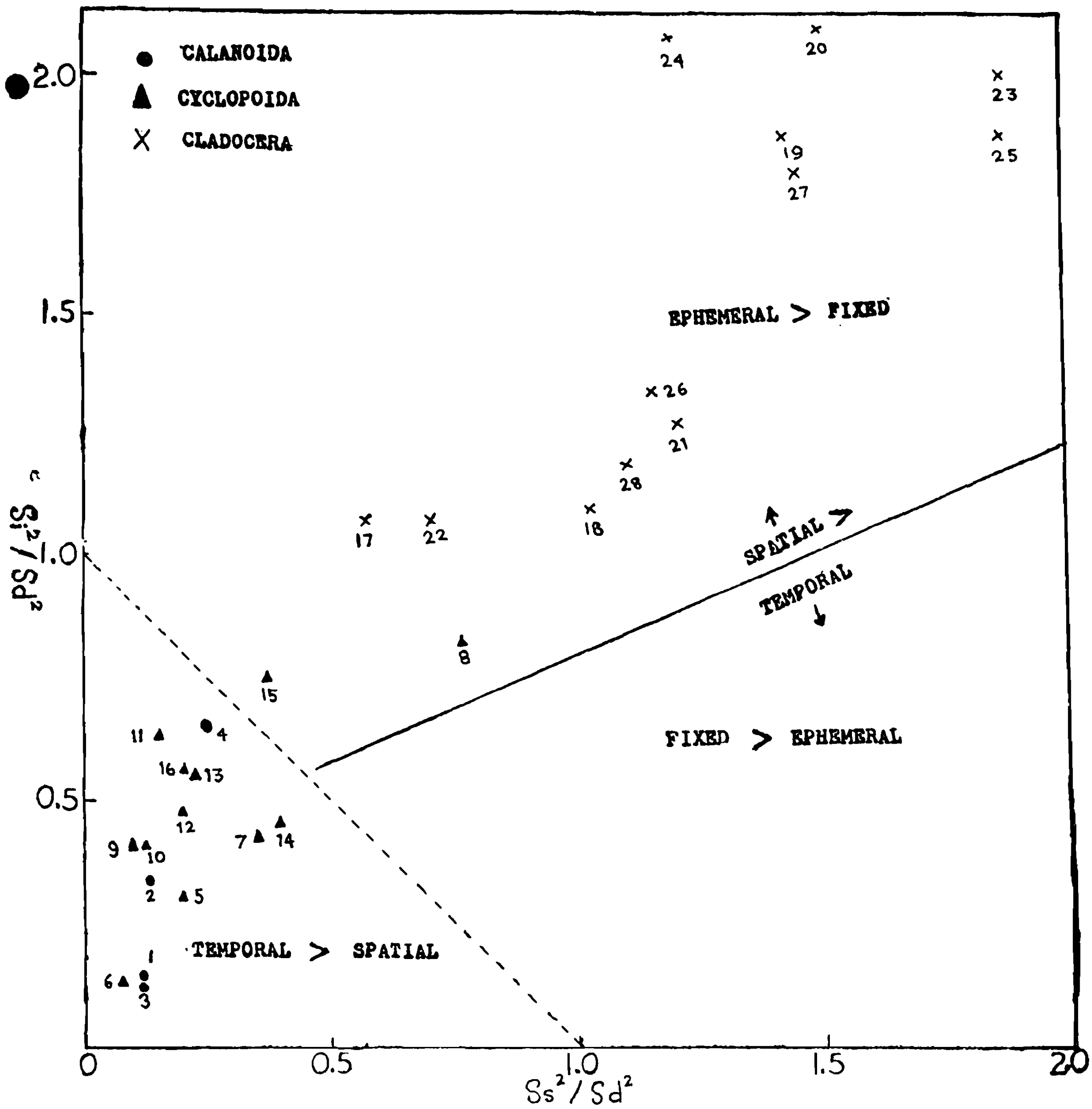

Fig. 2. Ratios of variance components plotted against each other to show relative importance of spatial and temporal variations in zooplankton (Codes are from Table 1.)

bly with regards to relative importance of temporal or spatial differences. Both groups of copepods showed almost very stable relationship where temporal variance always dominated spatial variance. This indicates that these species have well established themselves in the lake. In cladocera, high ephemeral patchiness is a definite characteristic of all the three species. It is suggested by Lewis (1978) that ephemeral patchiness may be extremely important to the survival of these species in limnetic habitats.

The striking similarity between the result of Lewis and that of present study reveals that the variance component method can be successfully used for the comparison of spatio-temporal variations in freshwater crustacean zooplankton. However more studies involving extensive comparison of lakes and reservoirs are required to establish the utility of the method.

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