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SOME ASPECTS OF INDEX OF DISPERSION OF NEGATIVE BINOMIAL DISTRIBUTION OF FRESHWATER OLIGOCHAETE POPULATION

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ABSTRACT

The analysis of community in general and niche relation in particular among the organisms sampled from different habitats of a similar geographical and climatic condition is primarily based on the relative occurrence and relative abundance of the organisms. This signifies the importance of pattern of distribution of organisms in different habitats. Hence the distributional pattern of organisms becomes an important aspect of ecology and community analysis Dispersion parameter is one of the two components to describe contagious distribution. The index of dispersion is a measure of extent of clumping of the organisms. The higher value of index of dispersion eventually approaches to that of Poisson. The index of disperson of eleven freshwater oligochaetes B. *sowerbyi,* Bedd., *L. hoffmeisteri* Steph., *T. tubifex* Steph., *A. americanus* Steph., *L.udekemianus* Steph., *L.angustepenis* Steph., *Aelosoma* sp Ehrbg., *Dero* sp Oken., *D. limosa* Steph., *Chaetogaster* sp K.Baer. and *Pistina* sp. Ehrbg. has been analysed and the annual mean values were 7.712. 1.725, 3.952, 0.150, 2.283, 5.835, 5.386, 4.996, 0.836. 0.843, 0.641 respectively. The annual average of dispersion parameter for the above species never reached more than 8. The paper deals with discussion on index of dispersion.

KEY WORDS
Oligochaete
Index of dispersion
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INTRODUCTION

Density, diversity and distribution of organisms with respect to time and space are basic prerequisites of ecological study. Distribution patterns are however, of very high ecological as well as ethological importance. Very little information is available on this aspect of study. The review of literature reveals that no systematic work has been done on distributional pattern of macrobenthic fauna of freshwater habitats. There is piling of literature available on seasonality of macrobenthic fauna (Anderson and Hooper 1956; Bishop and Hynes, 1969: Armitage *et al.,* 1974; Armitage 1976; Abraham, 1978; Cowell and Vidopich 1981; Sinha *et al.,* 1997). In India most of the authors have investigated macrobenthic fauna with particular reference to physico-chemical characteristics of soil and/or water and also the monthly variation in their population density (Govind 1963; Krishnamurthy, 1966, 1971; Gore 1977; Adholia *et al.,* 1990; Sinha *et al.,* 1991; Bais *et al.,* 1992; Barbhyan and Khan 1992; Sinha *et al.,* 1994).

The analysis of community in general and niche relation in particular of the organisms sampled from different habitats of a similar geographical and climatic condition is primarily based on the relative occurrence and relative abundance of the organisms. This signifies the importance of pattern of distribution of organisms in different habitats. Hence the distributional pattern of organisms becomes an important aspect of ecology and community analysis (Sinha, 1995).

Techniques to measure abundance of biological organisms vary from simple presence/absence data to estimates of relative abundance, density, or population size. The specific technique used depends on the questions being asked, the most efficient technique to answer a given question, and the biological or logistical constraints that limit the use of each technique (Kendeigh 1944).

The equality of mean and variance of a sampled population is an important characteristic of the Poisson distribution, whereas for the binomial distribution the mean is always greater than the variance. The distribution of population when shows a variance larger than the mean it is referred to as negative binomial distribution.

The contagious distribution of an organism is described by two parameters the mean of the population in different habitats and the dispersion parameter (k) which is the measure of extent of clumping of the organisms concerned. As analysed by Katti and Gurland (1962) the higher values of k eventually approaches to that of Poisson.

One approach to deriving the negative binomial distribution is to assume that the count for each sampling unit is distributed as a Poisson variable with mean. This mean may itself be regarded as a random variable, which is distributed as a gamma distribution with mean. This mixture leads to the negative binomial distribution (Pielou 1969), and provides a plausible model to justify the use of the negative binomial distribution.

Flexibility of the negative binomial distribution to accommodate different values of k is an advantage when modeling frequency distributions. This characteristic implies that if populations are clumped, the distribution is modeled with overdispersion compared to a Poisson distribution (Ramakrishnan and Meeter 1993). Likewise, if the distribution of organisms conforms to complete spatial randomness the data can be modeled as a Poisson process. Thus the k parameter allows the negative binomial distribution flexibility to handle a wide variety of spatial patterns of animal or plant distributions, and to provide inference about the underlying spatial distribution. Manton *et al.,* (1981) used the negative binomial model as a model of variance components for categorical data.

The present communication intends to have basic information on the least studied aspects of macrobenthic ecology i.e. the pattern of distribution and dispersion parameter in tropical freshwater lentic habitats.

MATERIALS AND METHODS

Monthly collections of macrobenthic fauna were made from four sampling sites by means of Ekman's dredge (523 sq. cm.) or Vin Van dredge depending upon the substrate condition of the habitat. Three dredging constituted a sample for macrobenthic fauna which was sieved through metallic sieve (gauge 256 meshes/sq. cm.) at the end. The residual organisms were sorted out and preserved in laboratory. The samples were studied qualitatively and quantitatively; species and groupwise, and expressed as number per squire meter. Five different habitats were sampled simultaneously and the mean value of the five samples has been taken as the representative sample for further calculation, while the variance of population was calculated on the basis of five population data. Only the oligochaetes were taken into account for the present investigation.

The central place in binomial family is occupied by Poisson series which describes a random distribution. But there is an equal probability of an organism to occupy a place in space so that the presence of one individual does not influence the other. The Poisson series gives a curve which is described completely by one parameter for the variance (s^2) is equal to mean ($\bar{x}$). The observed mean ($\bar{x}$) and variance (s^2) of distribution was calculated as

$$\text{Mean } (\bar{x}) = \frac{\Sigma x}{N}$$

$$\text{Variance } (s^2) = \frac{\Sigma(fx^2)[(\Sigma fx^2)/N]}{N-1}$$

Where,

$\bar{x}$ = Number of organism/m^2
f = Frequency
N = Number of samples

When the variance (s^2) is less than mean or more than mean i.e.

$$\frac{\bar{x}}{s^2} < 1 \quad \text{or} \quad \frac{\bar{x}}{s^2} > 1$$

the distribution is more regular or uniform or even and contagious or clumped or aggregated respectively. The contagious populations have been described by the negative binomial (or Pascal) distribution (Bliss and Owen, 1958; Rojas, 1964; Lyons, 1964; Harcourt, 1965; Ibarra *et al.,* 1965). This distribution is described by two parameters, the mean ($\bar{x}$) and the exponent k which is the measure of amount of clumping and is often referred to as the- dispersion parameter.

Dispersion parameter k has been calculated (Katti and Gurland, 1962) as

$$k = \frac{\bar{x}^2}{s^2 - \bar{x}}$$

However, methods of Bliss and Fisher (1953), Debauche (1962), Legay (1963) are also available and used.

RESULTS AND DISCUSSION

The dynamics of macrobenthic population in general can be well expressed if some aspects like population density along with its regulating factor, temporal variation, species diversity and evenness are explained and worked out (Sinha *et al.,* 1991). The present investigation, though deals with distribution pattern and dispersion parameter (k) yet accommodates some fundamental aspects of population dynamics to substantiate the findings.One among several aspects of statistical analyses often overlooked in biological investigations has been taken into account.

A total of eleven species of aquatic oligochaetes *namely Branchiura sowerbyi. Limnodrilus hoffmeisteri* Steph., *Tubifex tubifex* Steph., *Aulodrilus americanus* Steph., *Limnodrilus udekemianus* Steph., *Limnodrilus angustepenis* Steph., *Aelosoma* sp. Ehrbg., *Dero limosa* Steph.,

Table 1: Seasonal variation in mean density of oligochaet population (number/m²)(n=5)

Name of species	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Branchiura sowerbyi	107.6	148.6	148.4	261.2	307.6	517.6	611.6	544.4	663.0	450.6	235.4	146.2
Limnodrilus hoffmeisteri	10.6	8.0	18.6	15.6	7.6	12.8	61.2	15.4	46.2	0	13.0	7.8
Tubifex tubifex	43.4	87.0	138.8	120.8	128.8	222.8	171.8	140.8	94.8	7.4	28.0	5.2
Aulodrilus americanus	0	0	0	0	5.4	7.6	5.4	5.4	5.2	0	0	0
Limnodrilus undekemianus	94.6	66.6	135.8	79.2	149.0	214.8	271.4	360.8	407.0	204.6	131.8	99.8
Limnodrilus angustepenis	71.6	56.4	110.0	125.4	125.4	186.8	151.2	284.8	217.6	64.2	94.6	66.8
Aelosoma sp.	56.4	53.8	64.0	105.2	87.0	194.6	140.8	140.6	140.6	209.0	64.2	94.6
Dero limosa	13.0	2.8	5.4	5.2	23.0	5.2	51.4	26.0	13.0	5.6	15.6	10.2
Chaetogaster sp.	12.8	20.6	15.2	7.8	5.2	30.6	33.6	13.0	5.2	8.0	25.4	41.2
Dero sp.	89.6	46.0	76.4	102.6	184.2	218.2	276.4	202.2	107.8	108.8	108.2	107.8
Pristina sp.	13.0	5.2	7.6	13.2	23.2	7.8	10.4	2.6	20.4	0	8.0	12.8

Chaetogaster sp. K.Baer., *Dero* sp. Oken., *Pristina* sp Ehrbg. were recorded as major component of community composition, belonging to three families -Tubificidae, Aelosomatidae and Naididae with considerable variation in population density and seasonal variation. The mean population density of *B. sowerbyi* was maximum in July (611.6) and minimum in January (107.6). *L. hoffmeisteri* was abundant in July (61.2) rare in February (8.0) and absent in October. The highest population of *T. tubifex* was recorded in June (222.8) and lowest in December (5.2). *A. americanus* was absent in most of the samples, while *L. udekemianus* and *L. angustepenis* were found in every sample throughout the period of investigation.

Aelosoma sp. was in considerable number showing highest population in July (53.8). Among other species like 0. *pectinata, Chaetogaster* sp., *Dero* sp. And *Prictina* sp., the *Dero* sp. was always found in higher number than the rest (Table 1). Considering the trend of population fluctuation, the month of July was most favorable period for almost all the species. The higher population density of oligochaets *after* the onset of rainy season may be due to increase in quantity of their choiced food- the organic materials (for naidids) and bacteria (for tubificids and some naidids) (Brinknurst, 1970) due to rise in both allochthonus and autochthonus materials and their subsequent degradation.

Similar to the mean population densities as presented in Table 1, the variance of their population varied (Table 2) considerably. The examination of Table 2 reveals that the variance value is always higher than the mean value (Table 1) for every species and in every month. The mean variance ratio determines the pattern of distribution and the results of mean (x) variance (s^2) ratio has been presented in Table 3. Since no value of mean and variance ratio is more than one, the whole oligochates taken into account show a negative binomial distribution and the pattern of distribution is contagious or clumped or aggregated. The oligochaetes have not shown the sign of regular or uniform distribution. To describe and assess the amount of clumping the dispersion parameter k has been determined and the values of k have been presented in Table 4. The value of k has shown a considerable variation. The data analysed for dispersion parameter revealed considerable variation in the value obtained for different species and also different species showed considerable variation with seasonal succession.

As shown in the table the *B. sowerbyi* showed maximum value of k 32.465 (November) while minimum as 1.479 (March). For *L. hoffmeisteri* 0.254 was the minimum value in August and 11.996 was the maximum value in March. *T. tubifex* showed the minima (0.259) and maxima (12.161) in October and June. For *A. americanus* the minimum and maximum values for dispersion parameter were 0.259 (June) and 0.759 (July) respectively whereas 6.734 in the month of July and 0.710 in the month of June were the highest and lowest values for *L. udekemianus*.

For *L. angustepenis* 32.154 was recorded as maximum dispersion parameter value in the month of January and the minimum value was 0.665 in February. For *Aeiosoma* sp. 7.820 (August) and 0.758 (February) were the highest and lowest values of dispersion parameter. 2.476 in the month of July and 0.263 in the month of June and April were recorded as the maxima and the minima of dispersion parameter score for *D. pectinata*. While *Chaetogaster* sp. scored 2.809 in November as highest and 0.258 in April as lowest value.

For *Dero* sp. highest and lowest values were calculated as 14.027 (April) and 0.245 (February). *Pristina* sp. showed 1.426 (April) and 0.259 (March) as the highest and lowest value.

The present study reveals that the oligochaetes taken into account show negative binomial distribution. When the number of organisms per unit shows a negative binomial distribution, the parameter k of the series is used as a measure of aggregation (Waters 1959 a and b) low values (usually less than 8) of dispersion parameter k indicate pronounced clumping and high values slight clumping. This parameter does not depend upon the population density. Even for higher population densities the value of

Table 2: Seasonal variation in variance of oligochaet (number/m²)(n=5)

Name of species	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Branchiura sowerbyi	4504.24	6415.04	15042.24	32548.56	8933.04	72730.24	83711.44	91838.64	35648.00	13686.24	1942.24	1080.16
Limnodrilus hoffmeisteri	168.64	115.60	47.44	225.04	231.04	260.16	4135.36	948.64	1069.76	0	135.2	96.04
Tubifex tubifex	1604.24	8632.8	11794.96	5702.96	1960.96	4304.56	8160.16	2273.36	4101.76	219.04	217.06	104.24
Aulodrilus americanus	0	0	0	0	116.64	231.04	43.84	116.64	108.16	0	0	0
Limnodrilus undekemianus	5851.84	3371.44	14407.36	3358.16	9176.80	65165.76	11210.24	89962.96	40844.8	18614.64	10189.76	5755.36
Limnodrilus angustepenis	231.04	4839.04	2144.00	6092.24	5790.24	7290.56	15587.76	10738.96	13695.04	3375.36	3673.84	1190.40
Aelosoma sp.	1937.04	3870.16	3459.2	1735.36	1678.80	16509.44	9664.56	2668.64	7109.60	1830.96	426.64	2855.36
Dero limosa	192.80	31.36	43.84	108.16	612.80	108.16	1118.24	458.00	192.80	47.04	615.04	218.56
Chaetogaster sp.	260.16	803.84	346.56	243.36	108.16	1467.04	1797.04	192.80	108.16	115.60	255.04	981.76
Dero sp.	2601.04	698.00	587.84	853.04	5596.24	4867.76	8104.16	16196.24	15629.76	5439.36	4634.16	3275.76
Pristina sp.	390.40	108.16	231.04	135.36	1581.76	108.16	94.64	27.04	296.64	0	110.40	260.16

Table 3: Table showing binomial distribution in different months of the year of oligochaet species

Name of species	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Branchiura sowerbyi	0.023888	0.023164	0.009865	0.008024	0.034433	0.007113	0.007306	0.005927	0.018598	0.032923	0.121200	0.1353
Limnodrilus hoffmeisteri	0.062855	0.069204	0.392074	0.069321	0.032894	0.049200	0.014799	0.016233	0.043187	0	0.096153	0.081216
Tubifex tubifex	0.027053	0.010077	0.011767	0.021181	0.065682	0.051759	0.021053	0.061934	0.023112	0.033783	0.128676	0.049884
Aulodrilus americanus	0	0	0	0	0.046296	0.032894	0.123175	0.046296	0.048076	0	0	0
Limnodrilus undekemianus	0.016165	0.019754	0.009425	0.023584	0.016236	0.003296	0.024210	0.004010	0.009964	0.010991	0.012934	0.017340
Limnodrilus angustepenis	0.309903	0.011655	0.051305	0.020583	0.021657	0.025622	0.009699	0.026520	0.015888	0.019020	0.017665	0.062163
Aelosoma sp.	0.029116	0.013901	0.018501	0.060621	0.051822	0.011787	0.014568	0.052686	0.029396	0.035063	0.221732	0.023394
Dero limosa	0.067427	0.089285	0.123175	0.048076	0.037532	0.048076	0.045965	0.056768	0.067427	0.119047	0.025364	0.046669
Chaetogaster sp.	0.049200	0.025626	0.043859	0.032051	0.048076	0.020858	0.018697	0.067427	0.048076	0.069204	0.099592	0.041965
Dero sp.	0.034447	0.065902	0.129967	0.120275	0.018298	0.037840	0.026924	0.017065	0.012936	0.019818	0.023348	0.032908
Pristina sp.	0.033299	0.048076	0.032894	0.097517	0.014667	0.072115	0.109890	0.096153	0.068770	0	0.072463	0.049200

Table 4: Seasonal variation in dispersal parameter (k) of different oligochaet species

Name of species	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Av.
Branchiura sowerbyi	2.633	3.524	1.479	2.113	10.970	3.707	4.501	3.246	12.564	15.340	32.465	2.885	7.952
Limnodrilus hoffmeisteri	0.711	0.595	11.996	1.162	0.259	0.662	0.919	0.254	2.085	0.000	1.383	0.606	1.725
Tubifex tubifex	1.207	0.886	1.653	2.613	9.055	12.161	3.659	9.296	2.243	0.259	4.135	0.263	3.952
Aulodrilus americanus	0.000	0.000	0.000	0.000	0.262	0.259	0.759	0.262	0.263	0.000	0.000	0.000	0.150
Limnodrilus undekemianus	1.554	1.342	1.292	1.913	2.459	0.710	6.734	1.453	4.096	2.274	1.727	1.761	2.283
Limnodrilus angustepenis	32.154	0.665	5.949	2.635	2.776	4.912	1.481	7.759	3.513	1.245	2.025	4.905	5.835
Aelosoma sp.	1.691	0.758	1.206	6.789	4.755	2.321	2.082	7.820	6.330	2.333	26.952	1.600	5.386
Dero limosa	0.940	0275	0.759	0.236	0.897	0.263	2.476	1.565	0.940	0.757	0.406	0.499	4.996
Chaetogaster sp.	0.662	0.542	0.697	0.258	0.263	0.652	0.640	0.940	0.263	0.595	2.809	1.805	0.836
Dero sp.	3.197	0.245	11.413	14.027	1.903	7.244	6.037	4.799	2.650	2.180	2.587	3.668	0.843
Pristina sp.	0.448	0.263	0.259	1.426	0.345	0.606	1.284	0.277	1.507	0.000	0.625	0.662	0.641

k is low and for low population densities high (Table 1 and 4). For instance, the highest population density of *B. sowerbyi* is 611.6 individuals / m^2 in the month of July while highest dispersion parameter value is 32.465 in the month of November, when population density is 235.4 individuals / m^2. Similarly the maximum k value for *L. hoffmeisteri* has been found to be 11.996 in the month of March when population is only 18.6 individuals / m^2 but at its highest population density (61.2 ind / m^2 in-July) the k value is considerably low (0.919) proving the independency of k with mean.

Biological count data probably are more frequently distributed as a negative binomial than as normal or Poisson. Although ANOVA is relatively robust to violations of normality when the data are distributed as a negative binomial (Mitchell 1977), it seems logically better to use a statistical model that is appropriate for the data being analyzed. The k parameter may also provide additional insight not explicit in ANOVA, Poisson regression, or contributing more information about the data being analyzed. Ecological insights can be gained by examining differences in treatment responses not reflected in means. With ANOVA or other parametric approaches, additional information can be gained from statistics that describe other aspects of the distribution such as the variance. Of equal biological interest is whether two populations are distributed similarly even if the means do not differ. Differences in distribution might be attributed to such things as habitat structure or patchiness. The k parameter provides at least an initial assessment of this (Bliss and Fisher 1953).

According to Pielou (1969) one interesting property of k is that it remains unaltered when a population decreases in size owing to random deaths. This property of k makes it a desirable measure of aggregation which is not altered by increasing or decreasing of population may they be by natality, mortality or by other environmental factors i.e. environmental resistance or favour. Hence the measure k - the dispersion parameter may be thought of as representing some intrinsic property of a spatial pattern irrespective of population density.

REFERENCES

Abraham. M. 1978. Studies on the bottom macrofauna of Bhawanisagar reservoir (Tamiinadu) *J. Inl*and *Fish Soc. India.* **11(2):** 41-48.

Adholia. U. N. Chakrawarty, A. Srivastava. V. and Vyas, A. 1990. Community studies on macro-zoobenthos with reference to limno-chemistry of Mansarovar Reservoir, Bhopal. *J. Natcon*. **2(2):** 139-154.

Anderson, R.O. and Hooper, F.F. 1956. Seasonal abundance and production *of* littoral bottom fauna in a Southern Michigan lake. *Trans. Am. Microse. Soc.* **75:** 259-270.

Armitage, P. D., Macttale, A. M. and Crisp, D.T. 1974. A survey of stream invertebrates in the Cow Green basin (Upper Teesdale) before inundation. *Freshwater* Biol. **4:** 369-398.

Armitage. P. D. 1976. A quantitative study of the invertebrate fauna of the river Tees below Cow Green Reservoir. *Freshwater Biol.* **6:** 203-240.

Bais, V.S., Yatheesh, S. and Agrawal, N.C. 1992. Benthic macroinvertebrates in relation to water and sediment chemistry. *J. Freshwater Biol.* **4(3):** 183-191.

Bishop, J. E. and Hynes, H. B. N. 1969. Upstream movement of the benthic invertebrate in the Speed River, Ontario. *J. Fish Res. Bd. Canada.* **26:** 279-298.

Bliss, C.I. and Fisher, R. A. 1953. Fitting the negative binomial distribution to bioligical data and note on the efficient fitting of the negative binmial. *Biometrics.* **9:** 176-200.

Bliss, C. I. and Owen. A. R. G. 1958. Negative binomial distributions with a common k. *Biornetnka.* **45:** 37-58.

Brabhyan, S.I. and Khan, A. A. 1992. Studies on structure and function of benthic ecosystem in an eutrophic body of water; temporal and spatial distribution of Benthos. *J. Freshwater Biol.* **4(4):** 239-247.

Brinkhurst. R.O. 1970. Distribution and abundance of tubificids (oligochaeta) species in Toranto Harbour Lake, Ontario. *J. Fish. Res. Bd. Can.* **27:**1961-1969.

Cowell, B.C. and Vodopich, D.S. 1981. Distribution and seasonal abundance in benthic macroinvertebrates. *Hydrobiologia.* **78(2):** 97-105.

Debauche, H. R. 1962. The structural analysis of animal communities of the soil. In Murphy, P.W. (Ed), Progress in soil zoology, pp. 10-25.

Gore, J. A. 1977. Reservoir manipulation and benthic macroinvertebrate in a river. *Hydrobiologia*. **55(2):** 113-123.

Govind, B.V. 1963. Preliminary studies on the Tungabhadra Reservoir. *Indian* J. *Fish*. **10(1)** A: 148-158.

Harcourt, D. G. 1965. Spatial pattern of the cabbage looper, *Trichoplusia sp.* on crucifers. *Ann.ent soc. Am.* **58:** 89-94.

Ibarra, E.L., Wallwork, J.A. and Rodriguez, 1965. Ecological studies of mites found in sheep and cattle pastures. I. Distribution pattern of Orbatid mites. *Ann. Ent. Soc. Am.* **58:** 153-9.

Katti, S. K. and Gurland, J. 1962. Efficiency of certain methods of estimation for the negative binomial and the Neyman type A distributions. *Biometrika* **49***:* 215-26.

Kendeigh, S. C. 1944. Measurement of bird populations. *Ecological Monographs*. **14:**67-106.

Krishnamurthy, K. N. 1966. Preliminary studies *on* the macrofauna of Tungbhadra reservoir. *Proc. India. Acad. Sci.* **632(B):** 96-102.

Krishnamurthy, K. N. 1971. Primary studies on the bottom biota of Pulicat lake. *J. Mar. Bioi. Assoc. India*. **13(2):** 264-269.

Legay, J.M. 1963. A propos de la repartition de la cecidomyie du Hitre, *Mikiola fagi*. Un example de distribution binomiale negative. *Ann. Epiphyt.* C **14:** 49-56.

Lyons, L.A. 1964. The spatial distribution of two pine sawflies and methods of sampling for study of population dynamics. *Can. Ent.* **94:** 655-66.

Manton, K. G., Woodbury, M. A. and Stallard, E. 1981. A variance components approach to categorical data models with heterogeneous cell populations: analysis of spatial gradients in lung cancer mortality rates in North Carolina counties. *Biometrics*. **37:**259-269.

Mitchell, J. H. 1977. A robustness study of the analysis of variance on negative binomial data. Master's thesis. University of Washington, Seattle, Washington, USA.

Pielou, E. C. 1969. An introduction to mathematical ecology. Wiley Interscience, New York 286 pp.

Ramakrishnan, V., and Meeter, D. 1993. Negative binomial cross-tabulation, with application to abundance data. *Biometrics*. **49:**195-207.

Rojas, B. A. 1964. La binomial negative y la estimacion de intensidad de plages en el suelo, *Fitotenia Latinamer.* **1(1):** 27-36.

Sinha, M. P., Sinha, R. and Mehrotra, P.N. 1991. Composition and dynamics of freshwater macrobenthic community. I. Oligochaeta. *Oikoassay*. **8(1 and 2):** 21-24.

Sinha, R., Sinha, M.P. and Mehrotra, P. N. 1994. Population dynamics of chironomid larvae (Dipetra: Chironomidae) in fresh water reservoir. *Indian J. Amm. Res.* **28(1):** 27-30.

Sinha, M.P., 1995. Studies of niche relation of some freshwater groups. D.Sc. thesis (unpublished) Ranchi University, Ranchi.

Sinha, R., Ojha, N.K., Das, S.K. and Sinha, M.P. 1997. Community composition, population dynamics and species diversity of macro benthic fauna of a tropical lentic freshwater body in *Recent Advances in Ecobiological Research*. Ed. M.P. Sinha, Vol - I**,** 123-174. APH Pub., New Delhi.