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ASHIS KUMAR HAZRA
GURUPADA MANDAL
AND
DHRUBAJYOTI PAHARI
Zoological Survey of India, M-Block, New Alipore, Kolkata-700 053

Edited by the Director, Zoological Survey of India, Kolkata

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INTRODUCTION

The earliest attempt to study the soil Fauna was made by Diem (1930) in the Alpine Soil. There after a series of workers have published on taxonomy, ecology of Collembolan as well as microbial communities in soil of different ecosystems in India and abroad *viz;* McAtee (1907); Brown (1912,13), Imms (1912), Thompson (1924), Wilson and Lyon (1926), Agrell (1941), Weis-Fogh (1955), Ramakrishna (1955), Sheals (1956,57), Christiansen *et at.* (1961 and '64), Choudhuri (1961, '62a, b and '63) Dunger (1964), Choudhuri and Roy (1971b and 71a, b) Hale (1967), Prabhoo (1967, '71a, b and '76), Rappoport (1967), Sing and Mukherjee (1971 and '73), Hazra *et at.* (1976), Mitra *et al.* (1977), Hazra (1976), Hazra and Choudhuri (1981, '83, 90), Hagvar (1960), Parkinson (1983), Veeresh (1900), Alfred *et al.* (1991), Chakraborty and Bhattacharya (1992) Sage *et al.* (1997), Hazra *et al.* (1999), Mitra *et al.* (1999).

Several Workers have studied the impact of heavy metals on microfauna and microflora, viz; William et al. (1977) Nordgren *et al.* (1985), Bengtsson *et al.* (1985b), Duxbury (1986), Hopkin(1986, '89), Hazra and Choudhuri (1990), Anissimova *et al.* (1993), Roane and Kellogg (1996), Chattopadhyay and Hazra (2000) and Hazra and Bhattacharyya(2003). From the above literature it was assumed that the research works on Soil-Biology have tried to assess the impact of different biotic and abiotic factors on the distribution and diversity of soil mesofauna with special reference to Collembola. In addition, impact of polluting agents like heavy metals as well as soil microbes on Collembola have also been analyzed. The review of literature further revealed that in Indian sub-continents, the research works on this field either lacking or fragmentary. The present investigation in order to have more or less clear and comprehensive picture on soil bacteria, actinomycetes, fungi and Collembola in relation to heavy metals in reclaimed wetland embankment site at Kolkata. It is in this context the present investigation was undertaken with the following objectives: to estimate the quantitative and qualitative composition of Collembola, fungi-bacteria-actinomycets communities in the studied sites; to study the seasonal abundance and population fluctuations of soil fauna with special reference to Collembola and soil micro flora; to compare the species composition of Collembola community with that or fungi and bacteria-actinomycets genera; to evaluate the edaphic/abiotic factor like temperature, moisture, pH, organic carbon, nitrate and phosphate including the heavy metals like mercury, copper and zinc and their level of concentration in study site; to assess the significance of soil microbial flora as well as the impact of edaphic factors and heavy metals on the population structure of Collembola.

MATERIALS AND METHODS

Sampling and extraction of Collembola

Soil samples were collected at random, at the rate of 3 samples per plot every month during January, 2003. Samples were drawn by using a stainless steel corer (inner cross sectional diameter 8.5 sq/cm) from a depth of 5 cm. Separate sample units were taken from each site for the soil microbes and estimations of soil parameters, heavy metals etc. The soil samples thus collected were kept immediately in sterile polythene packet and stored in 4°C in the laboratory. Extraction of soil samples were carried out by 'Expedition Funnel Apparatus' modified by Macfadyen (1953). A 40-watt bulb was used for Heat and light source. The extraction period was 72 hours.

Isolation of Soil Microbes (Bacteria, Actinomycetes and Fungi) (Photo 3&4)

Considering the variety of microorganisms harbored in soil, it is apparent that no single method can reveal the total microbial population. The techniques available to study the soil microorganisms, the 'dilution plate method' are most widely used. With wide acceptance and popularity there are many variations of this technique. Though the viable colony count from a plating of diluted soil suspension, however, it must be recognized that a single medium and a prescribed condition of incubation will not support the growth of all the species in any group of these microorganism. In the present investigation, sterile de-ionized double distilled water was used to prepare the soil suspension for dilution series. Nature of culture :

Isolation	Medium	Dilution grade	Temperature	Incubation
Bacteria	Luria agar	10^{-4}	37°C	24 hrs.
Actinomycetes	Starch-casein	10^{-4}	28°C	7 days
Fungi	Czapek-Dox	10^{-2}	30°C	72 hrs.

Analysis of Edaphic Factors

Fresh soil sample was dried immediately on a hot air oven at about 105°C in order to stop further bacterial action (some sample was kept separately for the analysis of nitrate and estimation of soil moisture). It was then allowed to cool and stored in desiccators. The dried soil passed through the 2 mm sieve, mixed and fractionated before analysis.

Soil thermometer was used to record the temperature of the soil. The pH of the soil was determined the **electric pH meter**, 'WTW- ph 320' The moisture of the soil sample was measured by the **'Oven Dry Method'** (Dowdeswell, 1959). The organic carbon of the soil was determined by **'Rapid Titration Method'** (Walkley and Black, 1934). The nitrate and phosphate of the soil was determined by using the microprocessor based universally accepted standard **single beamed photometer** SQ 118 (E. Mark, Germany made).

Analysis of Heavy Metals

Copper, Lead & Zinc: Extraction of soil sample : 0.1gm of sample was digested in a Teflon beaker with HNO_3 for one hour it was then allowed to evaporate a pasty mass on a hot plate. Take up 1 (N) HCL, transferred to a 100 ml volumetric flux to make up the volume. Measurement was done by Atomic Absorption Spectrometer. Water was aspirated at first, to test any drifting in the absorbance and instrument reading for water is set for zero. The calibration solution for the desired element in order of increasing absorbance was aspired and then the test suction followed by the blank at respective wavelength. Measuring wavelengths for Cu, Pb and Zn are 324.8 nm, 217 nm, & 213.9 nm respectively.

Mercury : Cold vapor atomic (Hg) absorption spectophotometric method was followed.

Extraction of soil sample : 1 gm of soil was leached with 5 ml H_2SO_4 and 5 ml HNO_3 for 10 minutes it was then kept on hot water bath for one hour. Allowed it to cool down and transferred to a 100 cc volumetric flask to make up the volume.

Measurement : Extracted solution was transferred to a 250 ml BOD bottle with aspirator for Mercury Analyzer (EC India make). 10 % $SnCl_2$ solution was added and shaken for 2 minutes. Measurement was carried out against the Blank and standard solution of 2 ppb $HgCl_2$.

LOCATION AND CHARACTERISTIC OF SAMPLING SITE (Photo 1&2)

The site is a dumping ground of city wastes, located by the side of Eastern Metropolitan By pass, Kolkata. The area is demarcated by "Organic fertilizer Pvt. Ltd." as 'Conversation of City Solid Wastes into Organic Fertilizer in Collaboration with Kolkata Municipal Corporation and Eastern Fertilizer Pvt. Ltd.' The main constituents of the dumped materials were household wastes. Industrial effluents and the residues of vegetables. In this sampling site cultivation of different vegetables (seasonal salad leaves, cauliflower, maize etc.) is practiced mixing the decomposing materials in the soil.

OBSERVATION

Soil Factors

Soil of this plot was blackish in colour and silty sand to sandy in texture. Mechanical analysis of soil sampled from this site showed maximum percentage of coarse sand 57.96%.The soil organic carbon and nitrate content were maximum in the month of March in each sampling year (3.95%, 3.7 ppm in 2003; 3.95%, 3.85 ppm in 2004, and 4.23%, 3.8 ppm in 2005) and in March the soil moisture were 35.9%, 34.9% and 34% in 2003, 2004 and 2005, respectively. The soil pH recorded minimum in March (5.8 in 2003, 5.9 in 2004 and 5.9 in

2005) In the month of May, the soil moisture was minimum (25.4% in 2003, 25.3% in 2004 and 27% in 2005), when the factors like soil temperature, pH and phosphate were minimum (39°C, 6.7, 3.6 ppm in 2003; 35°C, 6.7, 5.7 ppm in 2004 and 39°C, 6.9, 6 ppm in 2005) (Tab. 1a; Fig. 1a).

Heavy Metals

Month wise mean concentration of heavy metals in soil sample of the present site have been shown in Tab. 1b and Fig. 1b. from which it would be evident that, in March 2005 the concentration of heavy metals were low (Hg 0.57 ppm, Co 175 ppm, Pb 130 ppm and Zn 495 ppm).

Collembolan Fauna

The Collembolan fauna obtained from the study site belonged to species under 16 genera. The genus *Lepidocyrtus cyaneus* was the most dominant with 44.99% of the total fauna recorded from this site. The species *Xenylla obscura, Cyphoderus javanus, Seira indica, Cryptopygus thermophilus, Friesea yosii* and *Proisotoma (Clavistoma) fitchioides* represented 25.74%,19.55%, 2.71%, 2.5%, 1.6% and 1.07% respectively. Populations of other species were numerically low and highly irregular in distribution pattern (Tab. 1c; Fig. 2c). Percentage representation of Collembola was maximum during the month of March in each year of observation (Fig. 2d). The population maximum in March found to be coincided with the highest population of soil fungi and bacteria actinomycetes as well as maximum concentration of soil factors like organic carbon, nitrate and also with the minimum concentration of heavy metals like mercury, lead and zinc (Fig 1a-b, 1d).

Seasonal Changes

Figure 1c showed the seasonal changes in number of each predominant species of Collembola obtained from this site. *L. cyaneus* had a single peak in March in a year. While *X. obscura* showed its peak in February. C. *javanus* exhibited highest peak in March with a higher population in February. It is seen apparently that predominant forms of Collembola obtained from this site exhibited maximum population in February March and Minimum in May. The population peak of other genera species varied among years as well as months of observation due to their irregular occurrence in this field (Tab. 1c.).

Microbial Flora

Fungi The soil fungi obtained from this site belonged to 8 genera. The genus *Penicillium* was the most dominant occupying 64.63% of the total fungal population obtained from this site. The genus *Aspergillus* constituted 13.54% while *Fusarium* constituted 8.19% of total population. Other genera recorded were numerically poor and irregular in occurrence (Tab. 1d, Fig. 1e). The maximum percentage representation of fungi encountered in March every found to be coincided with the highest population of bacteria-actinomycetes as well as maximum concentration of soil factors like organic carbon, nitrate and also minimum concentration of soil pH and heavy metals like mercury, lead and zinc (Fig 1a-b, 1d).

Seasonal Changes

Figures 1g has shown the month wise numerical changes of the predominant genera of soil fungi recorded from this site. The *Penicillium* had its peak in March in each year of observation. *Aspergillus* had its highest peak in July 2003, second peak in March 2004, The maximum abundance of other genera varied among year as well as in months of observation due to their irregular occurrence in this field (Tab. 1d). In May, absence of some genera and poor occurrence of the dominant resulted in minimum population density of total fungi community.

Bacteria – Actinomycetes

The soil bacteria-actinomycets obtained from this site belonged to 10 genera. The genus *Bacillus* was the most dominant and represented 59.09% of the total population recorded. The genus *Streptomyces* occupied 12.29% and *Micrococcus* occupied 7.73%. In addition some more genera were also recorded from this field but, their occurrences were irregular (Tab. 1e, Fig. 1h). A maximum population of 4.37% was in March' 2003 and 5.84%, 5.81% observed in February and March in 2004 respectively. The high percentage of total bacteria-actinomycetes during March coincided with the high concentration of soil factors like organic carbon and nitrate, low value of pH and low concentration of heavy metals like Hg. Pb and Zn. The minimum population recorded in the month of May in each year coincided with that of Collembola and fungi as well as minimum content of soil moisture, phosphate and maximum value of soil pH (Fig. 1a-b, 1d).

Seasonal Changes

From figure 1i, it is evident that, population peak of dominant genera varied among years as well as in months of observation. The population of *Bacillus* showed an increasing trend from January' 2003 reaching peak in March, another peak was observed in December, the density was low between these two peaks; in 2004 the highest peak was in February and another in April but in remaining months it remained more or less high with slight fluctuation. The population of Streptomyces showed gradual trend in fluctuation with the highest peak in January' 2004. The third dominant genus Micrococcus was found to be very irregular, its population peaks were recorded in March, February and April respectively in the three consecutive year of study. The other genera also revealed irregular population peak due to their infrequent occurrence in this field. In May, absence of some genera accompanied with low population of pre dominant genera resulted in the minimum population density of total bacteria-actinomycetes community (Table 1e).

Table 1a : Values of edaphic factors per month at study site

Year	Month	Temperature (°C)	Moisture (%)	pH	Organic Carbon (%)	Nitrate (ppm)	Phosphate (ppm)
2	J	22	2720	6.2	3.63	3.15	11.2
0	F	29	34.6	6	3.8	3.68	7.8
0	M	35	35.9	5.8	3.95	3.7	820
3	A	37	30.1	6.1	3.95	3.5	5.5
	M	39	25.40.	6.7	3.71	2.65	3.6
	J	35	28.5	6.6	3.7	2.7	14.2
	J	35	33.6	6.4	3.57	2.75	13.5
	A	31.3	35.9	6.4	3.28	2.7	14.6
	S	34.1	31.3	6.5	3.5	3	14.6
	O	36	28.2	6.6	3.63	3	14
	N	24.7	27	6.6	3.5	3.12	12.9
	D	29	25.1	6.3	3.57	325	12.3
2	J	21	24.1	6.2	3.47	3.38	7.8
0	F	31	32.6	6.2	3.85	3.5	11
0	M	39	34.9	5.9	3.95	3.85	11.2
4	A	35	30.1	5.08	3.85	3	10.5
	M	35	25.3	6.7	3.2	2.7	5.7
	J	28	28	6.7	3.3	2.8	12.4
	J	34	33	6.5	3.47	2.85	14.6
	A	27	34	6.5	3.6	2.9	14.1
	S	36.5	30	6.6	3.95	3.1	14.5
	O	32	29.1	6.5	3.63	3.15	12.2
	N	30	27	6.6	3.95	3.23	11.9
	D	27	27	6.3	3.6	3.2	10.8
2	J	21	24	6.3	3.8	3.25	7.7
0	F	26	30.9	6.1	3.98	3.4	9.7
0	M	34	34	5.9	4.23	3.8	11
5	A	37	30	6.2	4	3	9.3
	M	39	27	6.7	3.66	2.9	6
	J	38	29.2	6.9	3.25	2.95	5.1

Table 1b : Values of edaphic heavy metals per month at study site

Year	Month	Mercury	Copper	Lead	Zinc
2	J	1.0	200	170	600
0	F	0.631	159	140	515
0	M	0.62	190	130	515
3	A	0.66	200	130	530
	M	0.95	195	180	530
	J	1.1	210	200	550
	J	4.2	200	200	570
	A	0.95	180	260	580
	S	1.3	190	300	620
	O	1.3	210	280	600
	N	1.2	205	270	610
	D	1.0	200	150	600
2	J	0.63	200	150	550
0	F	0.66	205	150	530
0	M	0.6	180	140	510
4	A	1.3	180	170	510
	M	106	200	200	530
	J	2	200	230	570
	J	1.3	175	260	550
	A	1.3	175	250	550
	S	2	205	320	615
	O	2	205	300	620
	N	1.6	200	250	610
	D	1.0	205	230	600
2	J	0.93	180	180	615
0	F	0.5	185	150	505
0	M	0.57	175	130	495
5	A	1.0	175	150	515
	M	1.0	180	150	510
	J	0.85	175	180	550

Table 1c : Abundance (no./sq.m) of individual collembolan species obtained per month from study site

				2	0	0	3					
Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lepidocyrtus cyaneus	1762.11	6519.82	440.52	1585.9	88.1	1057.26	1674.01	176.21	176.21	88.1	440.52	88.1
	-0.26	-0.96	0.065	0.23	0.013	0.15	0.25	0.026	0.026	0.013	0.065	0.013
Xenylla obscura				-	-	-		-	-		2555.06	528.63
					-			-		-	0.37	0.08
Cyphoderus javanus	1145.37	9339.2	9339.2	37356.82	1233.48	176.21	88.1	352.42	88.1	792.95	1850.22	528.63
	0.17	1.37	1.37	5.47	0.18	0.026	0.013	0.052	0.013	0.12	0.27	0.08
Seira indica		-	18942.76	-	-	-	-	-	-	-	-	
	-	-	2.71	-	-	-	-	-	-	-	-	
Cryptopygus thermophilus		-	881.05	-	-	-	-	-	-	-	-	
	-	-	0.13	-	-	-	-	-	-	-	-	
Friesea yosii	-	-	-	-	352.42	-	-	-	-	881.05	-	176.21
	-	-	-	-	0.052	-	-	-	-	0.13	-	0.026
Proisotoma (Clavistoma) fitchioides	-	-	-	2202.64	264.31	1057.26	88.1	88.1	881.05	-	1479.79	-
		-	-	0.32	0.039	0.15	0.013	0.013	0.13	-	0.22	
I. exploratorius	-	-	-	264.31	-	-	-	-	-	-	88.1	88.1
	-	-	-	0.039	-	-	-	-	-	-	0.013	0.013
Ballistrura bengalensis	-	-	-	-	352.42	-	-	-	792.95	-	-	-

Table 1c : *Contd.*

	2	0	0	3							
Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
	-		-	-	0.052	-		-	0.12	-	-	
Sminthurides appendiculatus		-			-	176.21	1057.36	1145.4		88.1	-	
	-		-		-	0.026	0.15	0.017	-	0.013		-
Calx sp.	-		-	-	-			-	-			
	-		-	-	-	-	-	-	-			
Isotomurus balteatus	-	-		-	-	-	-	-	-	88.1	1145.37	
	-				-			-		0.013	0.17	
I. heterolepis	-		-	176.21	88.1	176.21	88.1	-			-	
	-		-	0.026	0.013	0.026	0.013	-		-	-	-
Sphaeridia sp	-		-	-	-			264.31	-	-	-	
	-		-	-		-		0.039	-		-	
Archerontiella sp	-	-	-	-		-	-	-		-		
	-		-			-					-	
Isotomiella sp	-			-	-				176.21			
			-						0.026			
Willemia sp					176.21							
					0.026							

Table 1c : Contd.

	2004											
Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Lepidocyrtus cyaneus	88.1	1762.11	13785.5	4581.5	792.95	440.53	88.1	88.1	88.1	88.1	88.1	88.1
	0.013	0.26	20.21	0.67	0.12	0.065	0.013	0.013	0.013	0.013	0.013	0.013
Xenylla obscura	4.52.86	575.33	1246.7	10660.8	616.74	7400.88	1585.9	1538.8	7577.1	8193.83	5462.55	1145.37
	0.58	8.43	1.8	1.56	0.09	1.08	0.23	0.83	1.11	1.2	0.8	0.17
Cyphoderus javanus	176.21	8017.62	264.31	145.37	176.21	88.1	88.1	176.21	3612.3	6519.82	12.70.48	6784.14
	0.026	1.18	0.039	0.17	0.026	0.013	0.013	0.026	0.53	0.96	1.77	0.99
Seira indica	-	-	-	-	-	-	-	-	-		-	-
	-	-	-	-	-	-	-	-	-	-	-	-
Cryptopygus thermophilus	176.21	6286.34	264.31	88.1	88.1	528.63	176.21	264.31	2026.4	1850.22	176.21	88.1
	0.026	0.77	0.039	0.013	0.013	0.08	0.026	0.039	0.3	0.27	0.026	0.013
Friesea yosii	-	-	1586.9	528.63	88.1	1850.22	176.21	88.1	881.05	88.1	88.1	528.63
	-	-	0.23	0.08	0.013	0.07	0.0269	0.013	0.13	0.013	0.013	0.8
Proisotoma (Clavistoma) fitchioides	-	-	-	-	-	-	-	-	-	-	1233.48	-
	-	-	-	-	-	-	-	-	-	-	0.18	-
I. exploratorius	-	528.63	1762.11	704.84	-	-	-	-	-	-	-	88.1
	-	0.08	0.26	0.1	-	-	-	-	-	-	-	0.013
Ballistrura bengalensis	-	-	-	-	-	1674.01	616.74	-	-	-	-	-
	-	-	-	-	-	0.25	0.09	-	-	-	-	-

Table 1c : *Contd.*

				2	0	0	4					
Species	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Sminthurides appendiculatus			-					-	-	-		
	-		-	-		-	-	-	-	-	-	
Calx sp.			-	-	-	1497.79	-	-	-	-		
	-	-	-	-	-	0.22	-	-	-			
Isotomurus balteatus			-	-	-		-		-	-		
	-	-	-	-	-	-	-	-		-		
I. heterolepis	88.1		-	88.1		88.1		-	88.1	-	-	
	0.013	-	-	0.013		0.013		-	0.013	-		
Sphaeridia sp	176.21	-	-	-		88.1	-	-	-	-	-	
	0.026	-	-	-	-	0.013		-				
Archerontiella sp	-	-	-	-	-	176.21	-	88.1	-	-		
		-	-	-		0.026	-	0.013	-		-	
Isotomiella sp			-			88.1			-			
						0.013		-				
Willemia sp						-			-			-

Table 1c : Contd.

	2	0	0	5		
Species	**J**	**F**	**M**	**A**	**M**	**J**
Lepidocyrtus cyaneus	2026.43	32599.11	104229.1	6255.5	792.95	969.16
	0.3	4.78	15.28	0.92	0.1	0.14
Xenylla obscura	2731.27	28634.36	9515.41	6960.35	792.95	1762.11
	0.4	0.42	1.4	1.02	0.1	0.26
Cyphoderus javanus	881.05	17180.6	18590	4140.96	176.21	88.1
	0.13	2.52	2.72	0.6	0.026	0.013
Seira indica	-	-	-	-	-	-
	-	-	-	-	-	-
Cryptopygus thermophilus	440.52	1850.22	1762.11	176.21	88.1	176.21
	0.065	0.27	0.26	0.026	0.013	0.026
Friesea yosii	-	-	264.31	88.1	176.21	88.1
	-	-	0.039	0.013	0.026	0.013
Proisotoma (Clavistoma) fitchioides	-	-	-	-	-	-
	-	-	-	-	-	-
I. exploratorius	88.1	440.52	-	176.21	-	-
	0.013	0.065	-	0.026	-	-
Ballistrura bengalensis	-	-	-	-	-	-
	-	-	-	-	-	-
Sminthurides appendiculatus	-	-	-	-	-	-

Table 1c : Contd.

	2	0	0	5		
Species	**J**	**F**	**M**	**A**	**M**	**J**
	-	-	-	-	-	-
Calx sp.	-	-	440.52	-	-	-
	-	-	0. 065	-	-	-
Isotomurus balteatus	-	-	-	-	-	-
	-	-	-	-	-	-
I. heterolepis	-	176.21	-	-	-	-
	-	0.026	-	-	-	-
Sphaeridia sp	-	-	-	-	-	-
	-	-	-	-	-	-
Archerontiella sp	-	-	-	-	-	-
	-	-	-	-	-	-
Isotomiella sp	-	-	-	-	88.1	-
	-	-	-	-	0.013	
Willemia sp	-	-	-	-	-	-
			-	-		-

Table 1c : *Contd.*

	2	0	0	5		
Genera	**J**	**F**	**M**	**A**	**M**	**J**
Penicillum	26 2.05	55 4.33	59 4.64	43 3.38	16 1.26	25 1.97
Aspergillus	5	5	9	3	1	4
	0.39	0.39	0.71	0.24	0.08	0.08
Fusarium	-	-	-	1	1	-
	-	-	-	0.08	0.08	-
Trichoderma	-	-	8	2	-	-
	-	-	0.63	0.16	-	-
Cephalosporium	-	-	-	-	-	-
	-	-	-	-	-	-
Mucor	-	-	-	-	-	-
	-	-	-	-	-	-
Rhizopus	-	-	-	-	-	-
	-	-	-	-	-	-
Sclerotium	-	-	-	-	-	-
	-	-	-	-	-	-

Table 1d : Abundance (no. x 1000/gm. Soil) of individual fungal genera obtained per month from study site

	2003											
Genera	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Penicillum	33	38	25	18	7	16	13	2	42	20	33	23
	2.6	2.99	1.97	1.42	0.55	1.26	1.02	0.61	1.89	1.57	2.6	1.81
Aspergillus	2	9	2	10	6	6	15	2	6	9	12	9
	0.16	0.71	0.16	0.79	0.47	0.47	1.18	0.16	0.47	0.71	0.94	0.71
Fusarium	-	-	-	9	-	-	-	14		7	-	1
	-		-	0.71	-	-	-	1.1	-	0.55	-	0.08
Trichoderma	- .	-	24			8	2	1	2			
	-		1.89		-	0.63	0.16	0.08	0.16		-	
Cephalosporium	-	-	-		-	-						10
			-			-				-		0.79
Mucor	-			5	3	2	2	3		2		
	-			0.39	0.24	0.16	0.16	0.24	-	0.16	-	
Rhizopus		-				-	8					1
	-				-		0.63				-	0.08
Sclerotium	-											

Table 1d : *Contd.*

	2004											
Genera	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Penicillum	23	5	55	46	14	33	14	28	29	22	50	26
	1.81	0.39	4.33	3.62	1.1	2.6	1.1	2.2	2.28	1.73	3.94	2.05
Aspergillus	4	2	13	1	5	5	5	3	4	1	10	4
	0.31	0.16	1.02	0.08	0.39	0.39	0.39	0.24	0.31	0.08	0.79	0.31
Fusarium	-	51	-	-	1	-	-	-	8			3
	-	4.02	-	-	0.08	-	-	-	0.71	-	-	0.24
Trichoderma	-	9	8	8	-	-	1	-		11	2	-
	-	0.71	0.63	0.63	-	-	0.08	-	-	0.87	0.16	-
Cephalosporium	-	-	-	-	14	-	-	-	-	16	-	-
	-	-	-	-	1.1	-	-	-	-	1.26	-	
Mucor	-	-	-	1	-	2	-	1	3	2	-	-
	-	-	-	0.08	-	0.16	-	0.08	0.24	0.16	-	-
Rhizopus	-	-	-	-	-	-	-	-	-	-	-	
	-	-	-	-	-	-	-	-	-	-	-	-
Sclerotium	-	-	-	-	-	-	-	3	1	-	-	
	-	-		-	-	-	-	0.24	0.08		-	

Table 1e : Abundance (no. X 1000/gm. Soil) of individual bacterial genera obtained per month from study site

	2003											
Genera	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacillus	33	49	71	47	21	36	29	14	10	5	13	72
	1.05	1.56	2.27	1.5	0.67	1.15	0.92	0.45	0.32	0.16	0.41	2.29
Streptomyces	18	13	21	16	5	3	12	7	30	32	17	2
	0.38	0.41	0.67	0.51	0.16	0.09	0.38	0.22	0.96	1.02	0.54	0.06
Micrococcus	-	-	30	29	5	-	-	15	-	8		
	-		0.96	0.92	0.16	-	-	0.48	-	0.25	-	
Cytophaga	7	10	10	7		3	4	9		6	56	7
	0.22	0.32	0.32	0.22	-	0.09	0.13	0.29	-	0.19	1.79	0.22
Arthrobactor	8	2	-	-		-	1	11	8	8	11	
	0.25	0.06		-	-	-	0.03	0.35	0.25	0.25	0.35	-
Promicromonospora	-	9	5	3	-	-	-	6		13	13	
	-	0.29	0.16	0.09	-	-		0.19	-	0.41	0.41	-
Corynebacterium	-		-	-	-	-	6	1	13	36		
	-			-			0.19	0.03	0.41	0.41		
Pseudomonas	-			8		-	-		-	5	5	
	-	-	-	0.25	-	-	-	-	-	0.16	0.16	-
Staphylococcus	-			3			-			4		
	-		-	0.09		-				0.13		
E.coli						-		-		10		
										0.32		

Table 1e : *Contd.*

	2004											
Genera	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bacillus	25	136	71	119	58	43	80	94	125	120	122	85
	0.79	4.34	2.26	3.79	1.85	1.37	2.55	3	3.99	3.83	3.89	2.71
Streptomyces	50	13	21	6	13	7	3	5	8	1	5	17
	1.59	0.41	0.67	0.19	0.41	0.22	0.09	0.16	0.25	0.03	0.16	0.54
Micrococcus	19	25	20	15	-	-	-	10	-	-		8
	0.6	0.79	0.63	0.47	-	-	-	0.32	-	-	-	0.25
Cytophage	10	4	31	-	4	10	-	-	2	-	6	-
	0.32	0.13	0.99	-	0.13	0.32		-	0.06	-	0.19	-
Arthrobactor	14	-	23	-	-	41	20	-	7	-	-	14
	0.44	-	0.73	-	-	1.31	0.63	-	0.22	-	-	0.44
Promicromonospora	3	-	11	-	-	3	-	-	-	-	2	-
	0.09	-	0.35	-	-	0.09	-	-	-	-	0.06	-
Corynebacterium	4	-	3	-	-	-	-	-	-	-	-	2
	0.13	-	0.09	-	-	-	-	-	-	-	-	0.06
Pseudomonas	-	-	2	10	-	-	-	-	-	-	-	10
	-	-	0.06	0.32	-	-	-	-	-	-	-	0.32
Staphylococcus	6	5	-	-	-	-	-	-	-	-	-	2
	0.19	0.16	-	-	-	-	-	-	-	-	-	0.06
E.coli	-	-		-	-	7	-	-	-	-	-	-
	-	-		-	-	0.22	-	-	-	-	-	-

Table 1e : Contd.

	2	0	0	5		
Genera	**J**	**F**	**M**	**A**	**M**	**J**
Bacillus	59	73	70	80	38	53
	1.88	2.33	2.23	2.55	1.21	1.69
Streptomyces	10	16	15	13	9	3
	0.31	0.51	0.47	0.41	0.29	0.09
Micrococcus	-	-	24	31	3	-
	-	-	0.77	0.99	0.09	-
Cytophaga	-	8	10	11	-	-
	-	0.25	0.32	0.35	-	-
Arthrobactor	9	3	15	2	-	-
	0.29	0.09	0.48	0.06	-	-
Promicromonospora	-	-	9	10	-	-
	-	-	0.29	0.32	-	-
Corynebacterium	-	-	-	-	-	-
	-	-	-	-	-	-
Pseudomonas	-	-	5	-	-	-
	-	-	0.16	-	-	-
Staphylococcus	2	-	-	-	-	2
	0.06		-	-	-	0.06
E.coli	-		-	-	-	3
	-		-	-	-	0.09

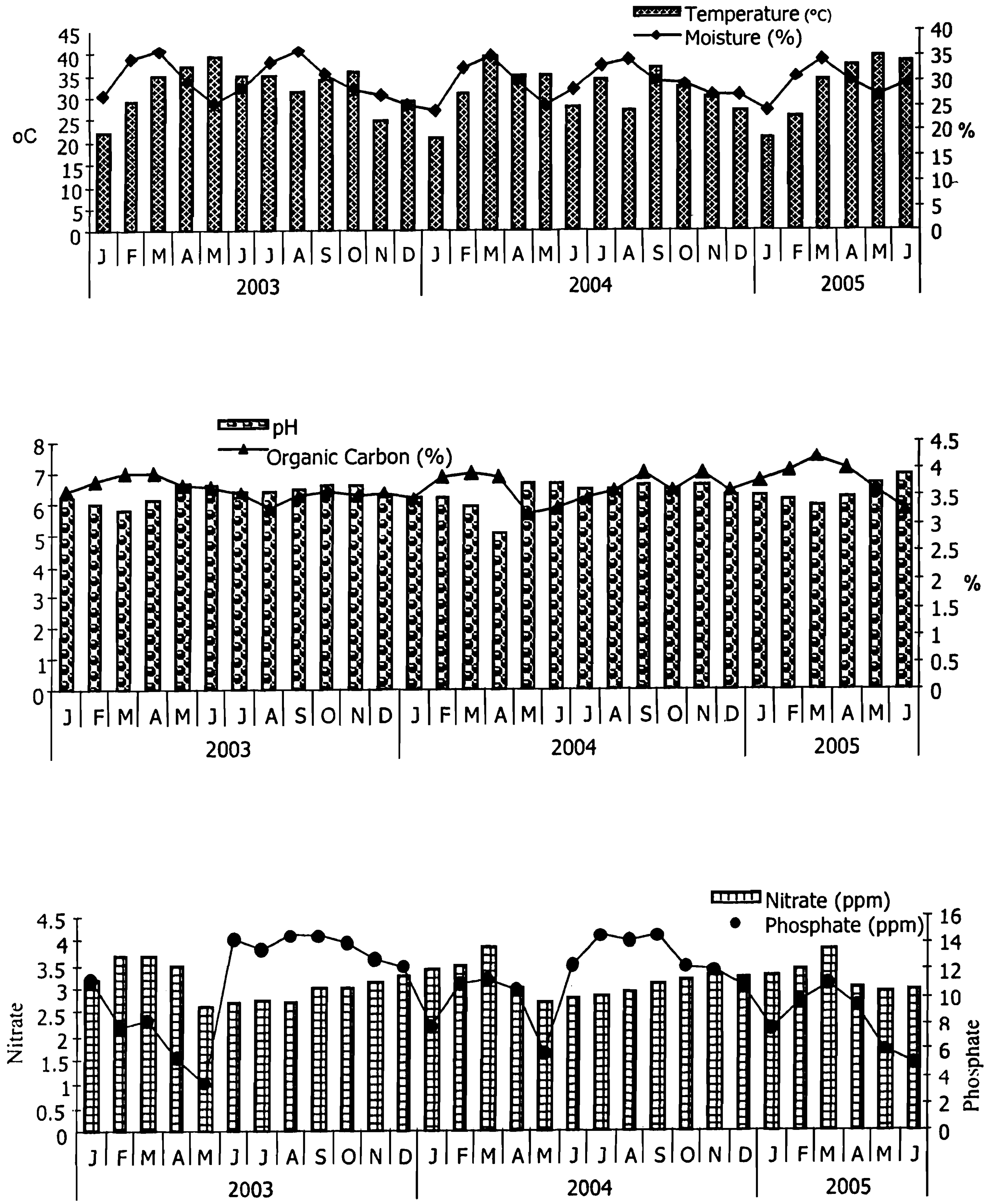

Fig. 1a : Monthly changes of edaphic factors at study site

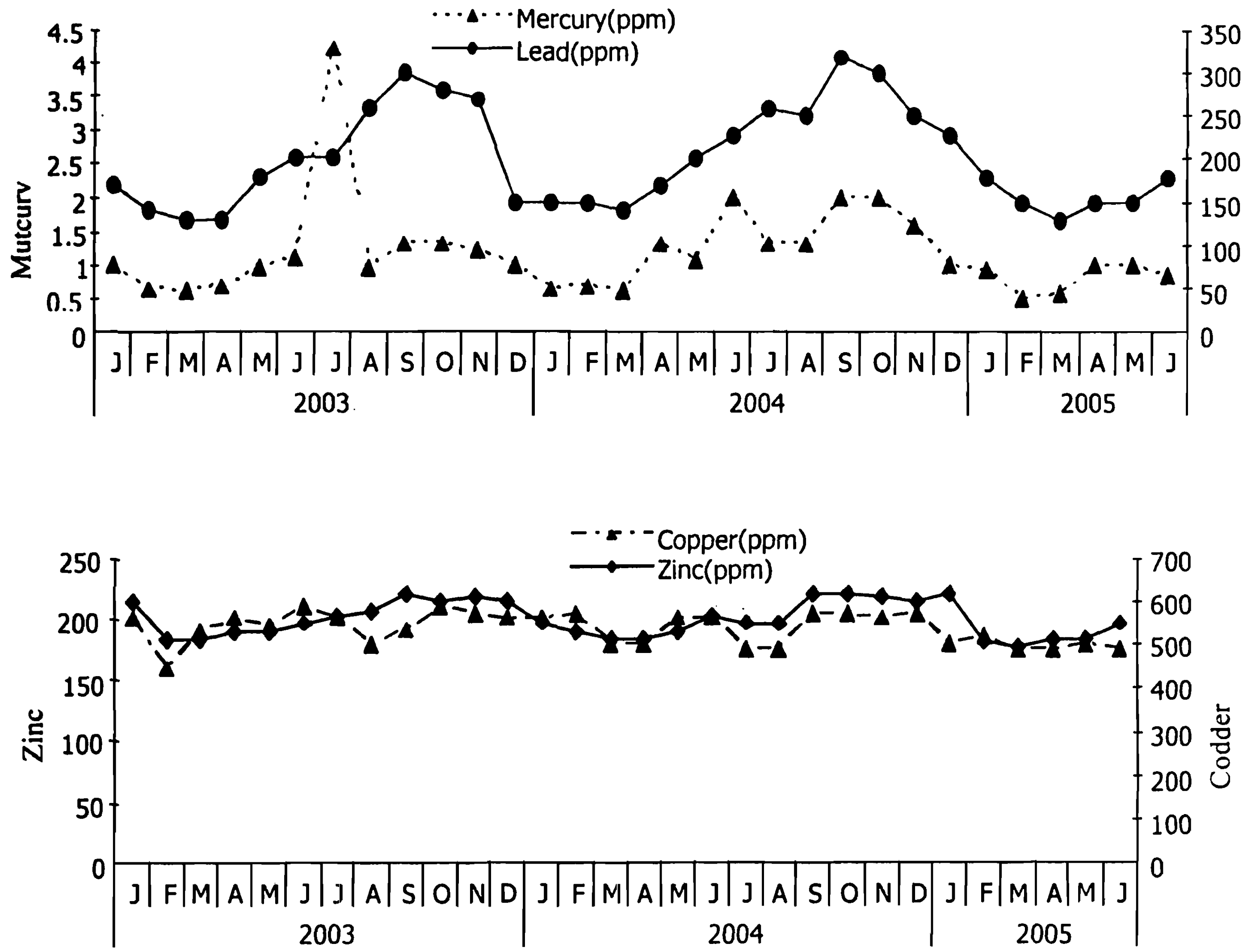

Fig. 1b : Monthly changes of heavy metal levels in soil at the study site

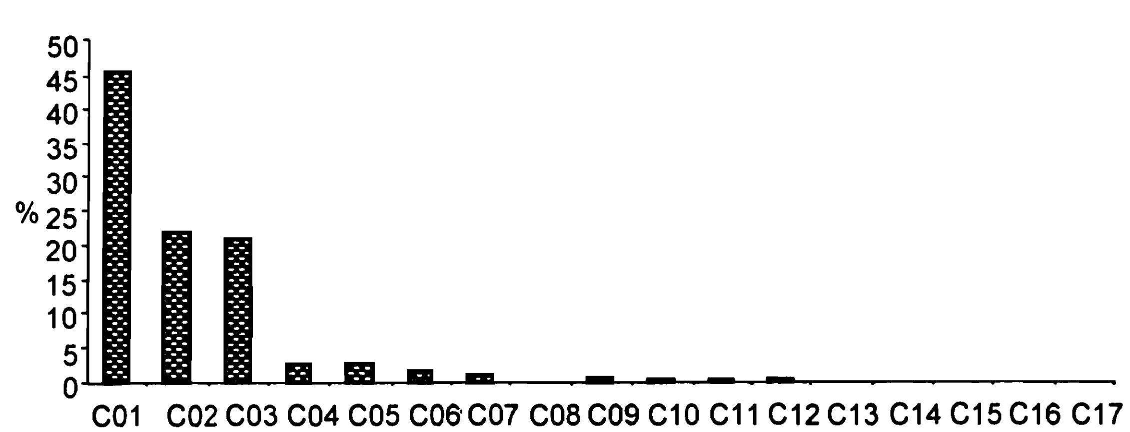

Fig. 1c. : Composition of collembolan community in study site. C01. *Lepidocyrtus cyanus*; C02. *Xenylla obscura*; C03. *Cyphoderus javanus*; C04. *Seira indica*, C05. *Cryptopygus thermophilus*; C06. *Friesea yosii*; C07. *Proisotoma (Clavistoma) fitchioides*; C08. *I. exploratorius*; C09. *Ballistrura bengalensis*; C10. *Sminthurides appendiculatus*; C11. *Calx sp.*;C12. *Isotomurus balteatus*; C13 *I. heterolrpis*; C14. *Sphaeridia sp*; C15. *Archerontiella sp*; C16. *Isotomiella sp*; C17. *Willemia sp*

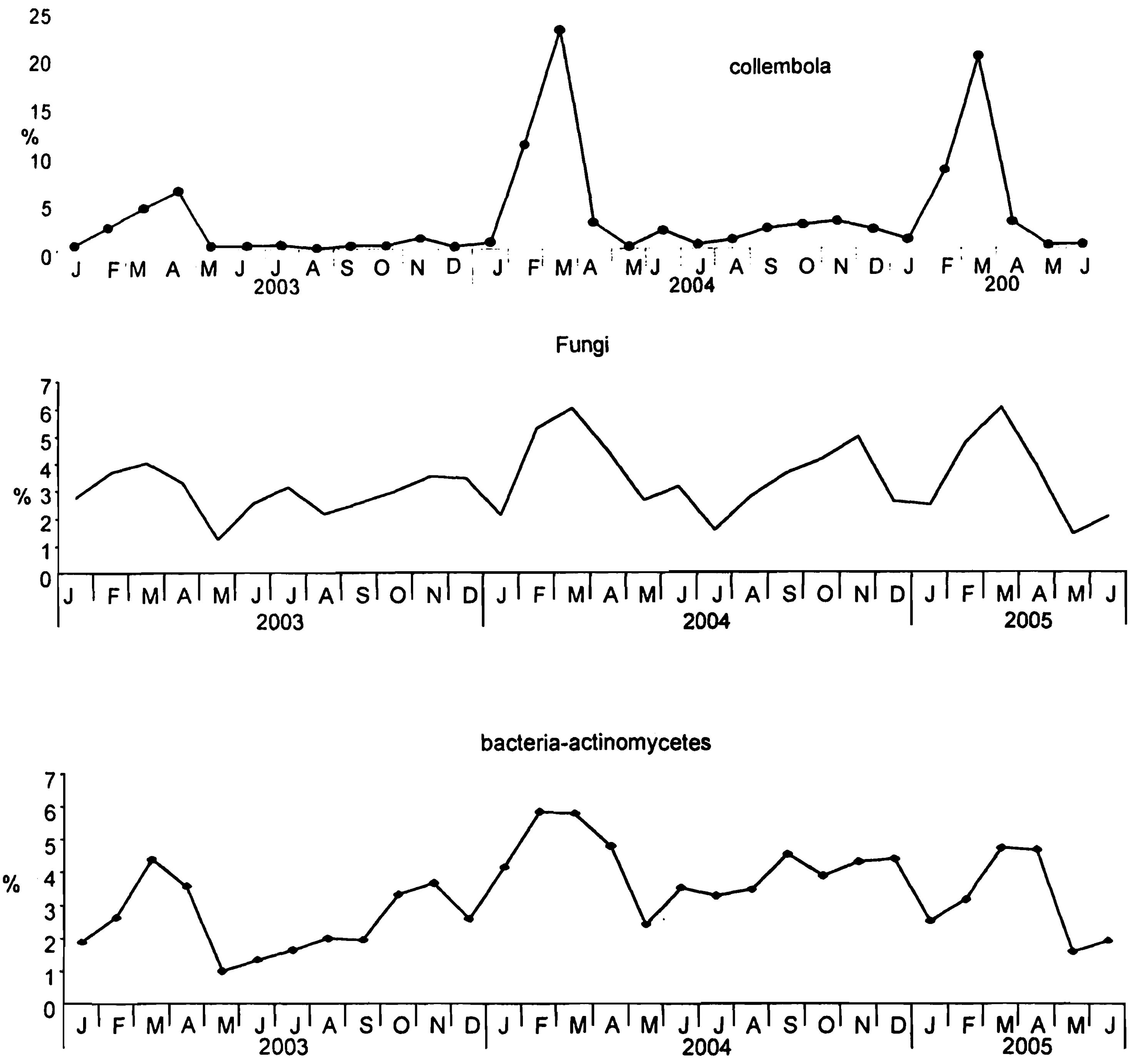

Fig. 1d. : Monthly fluctuation of Collembola, fungi and bacteria-actinomycetes

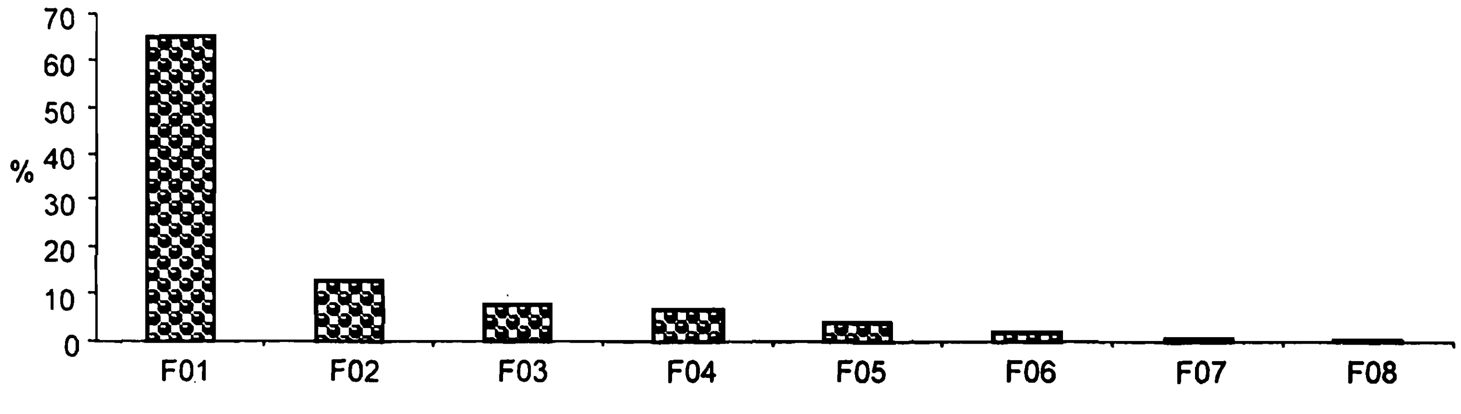

Fig. 1e. : Composition of fungal community. F01. *Penicillum*; F02. *Aspergillus*; F03. *Fusarium*; F04. *Trichoderma*; F05. *Cephalosporium*; F06. *Mucor*; F07 *Rhizopus*; F08. *Sclerotium*

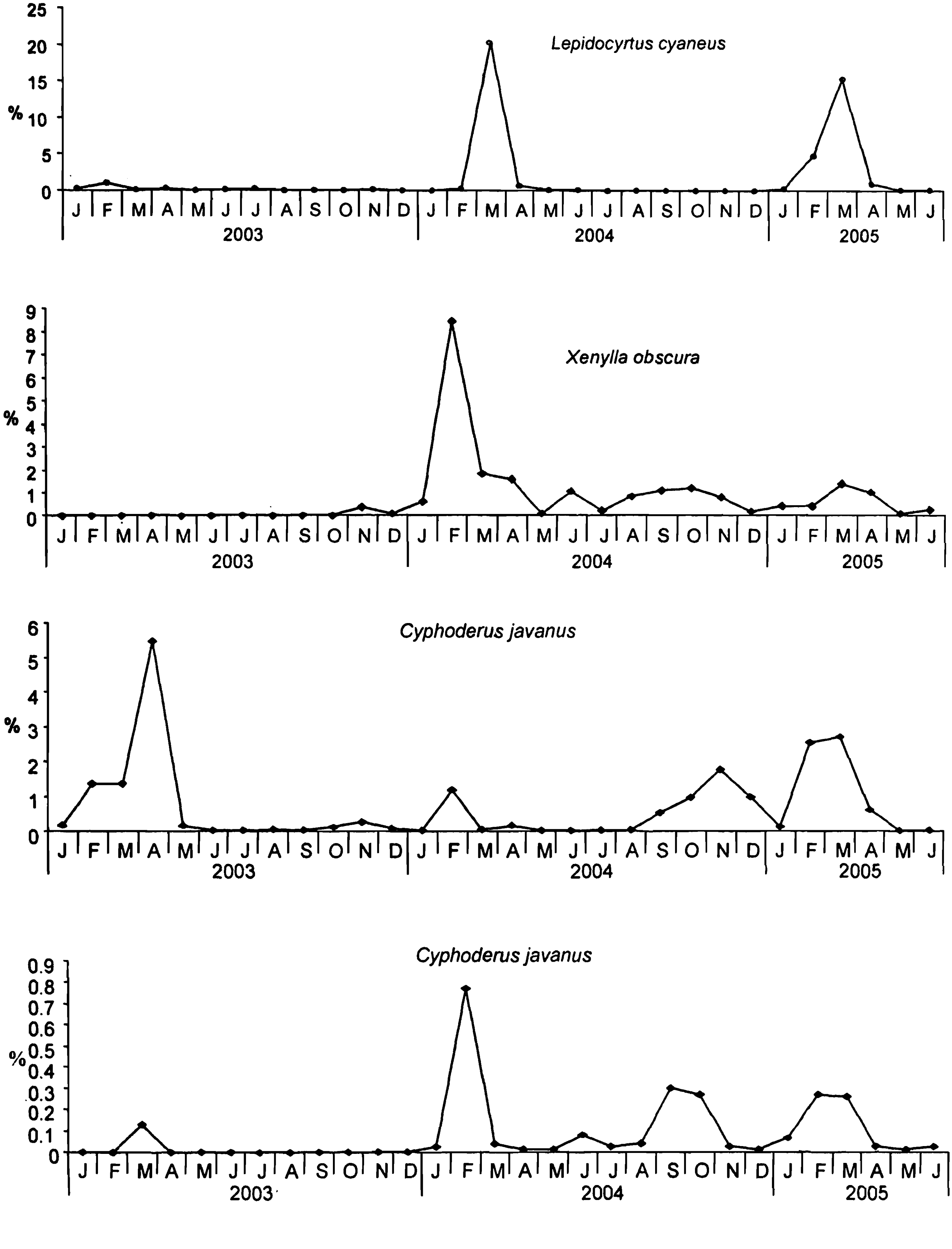

Fig 1f. : Monthly fluctuations of dominant species of Collembola

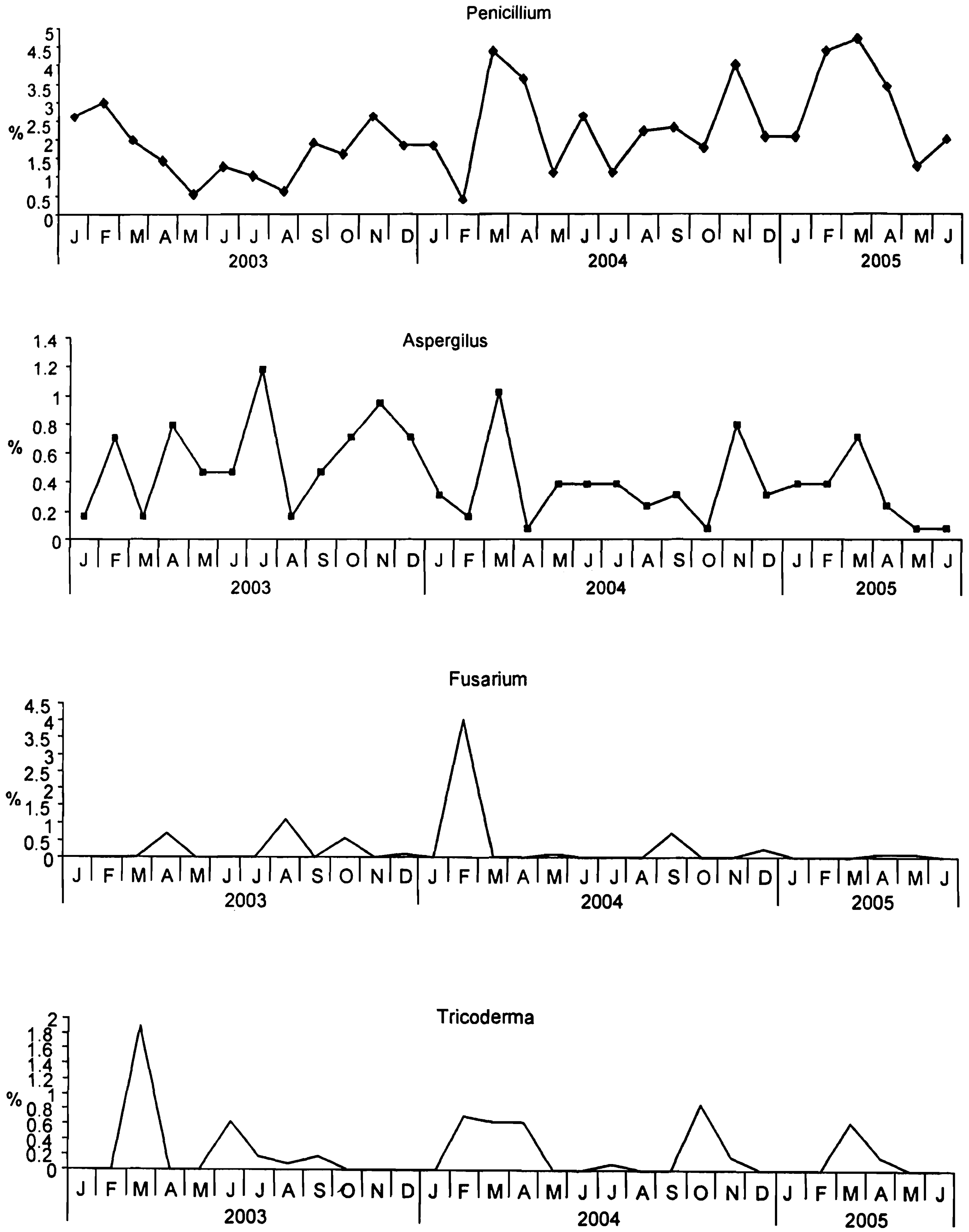

Fig.1g. : Monthly fluctuation of dominant fungal genera

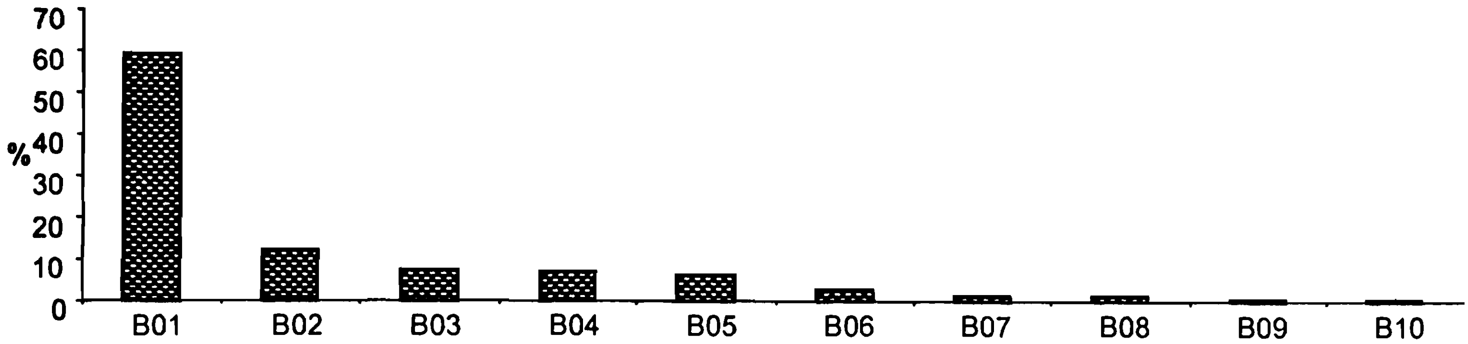

Fig.1h. : Composition of bacteria-actinomycetes community. B01. *Bacilus*; B02. *Streptomyces*; B03. *Microccus*; B04.*Cytophaga*; B05 *Arthrobactor*; B06. *Promicromonospora*; B07. *Corynebacterium*; B08. *Pseudomonas*; B09. *Staphyloccus*; B.10. *E. coli*.

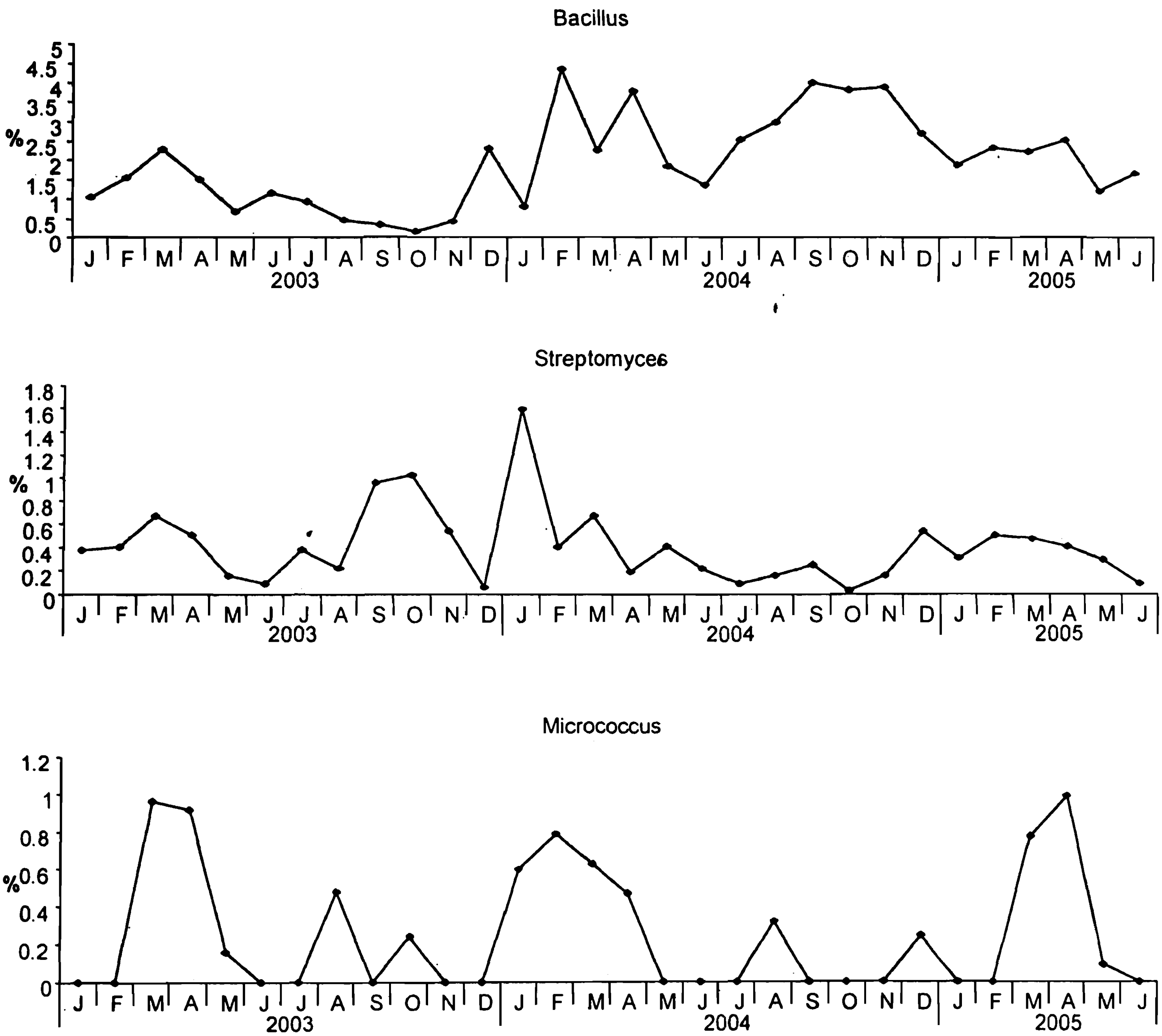

Fig.1i. : Monthly fluctuations of dominant Bacteria-actinomycetes

STATISTICAL ANALYSIS OF DATA

The statistical analysis of the complex soil faunal communities has been conducted to show the relationship between the soil factors and soil microorganisms. The application of LINEAR CORRELATION, ANOVA, STEP WISE REGRESSION and TWO WAY ASSOCIATION were undertaken in the present study involving the data of soil factors, heavy metal content and floral and faunal population densities of soil separately for each site. All the analysis has been carried out by sing BMDP Statistical Software.

Linear correlation

The correlation coefficient ('r' value) of each variable (i.e., total population of Collembola, fungi and bacteria-actinomycetes, six edaphic factors and four heavy metals) in this site was shown (Table 2). The correlation revealed identical relationship between the biotic variables in this site, of which the relationship between Collembola and fungi were strongly significant. But the bacteria-actinomycetes showed respective significant correlation only in waste disposal site (Table 2). The correlation coefficient data mentioned in the above tables broadly indicated that the edaphic factors like moisture, organic carbon, nitrate and phosphate with all the three biotic variables showed strong positive correlation in the study site.

Table. 2 : Correlation between different variables in the study site

	Cxx	Fxx	Bxx	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10
Cxx	1												
Fxx	1.86*	1											
Bxx	1.59*	1.70*	1										
S01	0.15	0.04	-0	1									
S02	.37**	0.35	0.34	0.4	1								
S03	0.55*	-0.5	-0.3	0	-0.4	1							
S04	0.60*	0.7	0.52	0.15	0.33	-0.4	1						
S05	0.76*	0.66	0.45	0	0.01	-0.6	0.44	1					
S06	0.01	0.18	0.18	-0.2	0.33	0.08	-0.1	-0.4	1				
S07	-0.3	-0.2	-0.2	-0.1	0.09	0.26	-0.3	-0.5	0.38	1			
S08	-0.3	-0.1	0	-0.2	-0.5	0.31	-0.1	-0.2	0.17	0.29	1		
S09	0.41**	-0.3	-0.1	-0	-0.1	0.46	-0.6	0.64	0.64	0.46	0.29	1	
S10	0.49**	-0.3	-0.2	-0.4	-0.4	0.38	-0.6	-0.6	0.49	0.38	0.49	0.74	1

*= significant at 1 %, ** = significant at 5 %; Cxx = Total collembolan population, Fxx = Total fungal population, Bxx = Total bacterial population, S01 = Temperature, S02 = Moisture, S03 = pH, S04 = Organic carbon, S05 = Nitrate, S06 = Phosphate, S07 = Hg, S08 = Cu, S09 = Pb, S10 = Zn

Step Regression Analysis

To determine the effects of fungi, bacteria and soil factors on the collembolan community usually the linear regression technique is followed. But, in that case, the factors are assumed to be independent, which is rather inapplicable. Therefore, Stepwise Linear Regression analysis was carried out, with the inclusion of a new factor already considered at every stage. However, there is no a priori theory about which factor or factors (biotic/abiotic) are most important. The steps were not been repeated until all the factors were included in the model. In this study, the predominant species of Collembola in a given site were considered as dependable variables and the observations of analysis were continued till the factors considered the improvement value up to 1 % level. The results of tests are showed in the table 3.

It this study site, the occurrence of different predominant collembolan species found to be regulated by single most important factor (like, only the fungi *Trichoderma* have most impact on the population of fourth dominent species *Seira indica)* as well as by maximum of seven factors (Table 3.). The effects of following seven factors namely, Penicillium, Cephalosporium, zinc, Arthrobacter, Aspergillus, Fusarium and copper were important on the population desity of the most dominant species *L. cyaneus* in site II. While the abundance of third dominent species *Cyphoderus javanus* was governed by the following seven factors, namely, *Trichoderma, Cephalosporium,* pH, copper, phosphate and zinc. Table 3 showed that the occurrence of second and fifth dminant species *Xenylla obscura* and *Cryptopygus thermophilus* were influenced only by two *(Fusarium* and *Bacillus)* and three *(Fusarim, Penicillium* and *Promicromonospora)* biotic factors respectively. Table 3 showed that the abudance of fourth dominant species *Cyphoderus javanus* was influenced by the following seven factors namely, *Rhizopus, pH, Mucor, Trichoderma, Sclerotium, Arthrobacter* and copper. However, only one two factor / factors showed their impact on the population density of *Cryptopygus thermophilus* in this study site. (Table 3).

Table 3 : Summary table of Step Regression Analysis of Study Site

Variable used = CO1, CO2, CO3, C10, C12, F01 to F08, B01, to B05, B09 to B13, S01 to S10

Independent variables = F01 to F08, B01 to B05, B09 to B13, S01 to S10

Dependent variable = C01 (= *Lepidocyrtus cyaneus*)

Step No.	Variable Entered	Multiple		Change in RSQ	Adjust RSQ	F Ratio	DF
		R	RSQ				
1	F01	0.6071	0.3686	0.3686	0.3464	16.34	1.28
2	F08	0.6884	0.1054	0.1054	0.4349	12.16	2.27
3	S10	0.7748	0.1263	0.1263	0.5541	13.01	3.26
4	B03	0.8232	0.0775	0.0775	0.6262	13.14	4.25
5	F02	0.8589	0.0599	0.0599	0.683	13.5	5.24
6	F03	0.8769	0.0313	0.0313	0.7087	12.76	6.23
7	S08	0.8977	0.0369	0.0369	0.7441	13.04	7.22

Dependent variable = C02 (= *Xenylla obscura*)

Step No.	Variable Entered	Multiple		Change in RSQ	Adjust RSQ	F Ratio	DF
		R	RSQ				
1	F03	0.7748	0.6003	0.6233	0.586	42.04	1.28
2	F01	0.8629	0.7446	0.1444	0.7257	39.37	2.27
3	B09	0.8989	0.808	0.0634	0.7858	36.47	3.26

Dependent variable = C03 (= C*yphoderus javanus*)

Step No.	Variable Entered	Multiple		Change in RSQ	Adjust RSQ	F Ratio	DF
		R	RSQ				
1	F04	0.7657	0.5863	0.5863	0.5715	39.68	1.28
2	F08	0.8137	0.6622	0.0758	0.6371	26.46	2.27
3	F01	0.8486	0.7201	0.0579	0.6878	22.29	3.26
4	S03	0.8583	0.7366	0.0165	0.6945	17.48	4.25
5	S08	0.8677	0.7528	0.0162	0.7013	14.62	5.24
6	S06	0.8739	0.7638	0.0109	0.7012	12.339	6.23
7	S10	0.8865	0.7859	0.0221	0.7178	11.54	7.22

Dependent variable = C10 (= *Cryptopygus thermophilus*)

Step No.	Variable Entered	Multiple		Change in RSQ	Adjust RSQ	F Ratio	DF
		R	RSQ				
1	F03	0.7945	0.6313	0.6313	0.6181	74.93	1.28
2	B01	0.8719	0.7601	0.1289	0.7424	42.78	2.27

Dependent variable = C12 (= *Seira indica*)

Step No.	Variable Entered	Multiple		Change in RSQ	Adjust RSQ	F Ratio	DF
		R	RSQ				
1	F04	0.7382	0.5449	0.5449	0.5287	33.53	1.28

Explanation: F01 = *Penicillum*, F02 = *Aspergillus*, F03 = *Fusarium*, F04 = *Trichoderma*, F05 = *Rhizopus*, F06 = *Mucor*, F07 = *Sclerotium*, F08 = *Ccephalosporium*, B01 = *Bacillus*, B02 = *Streptomyces*, B03 = *Arthrobactor*, B04 = *Micrococcus*, B05 = *Cytophaga*, B09 = *Promicromonospora*, B10 = *Pseudomonas*, B11 = *Corynebacterium*, B12 = *Staphylococcus*, B13 = *E. coli*.

TWO WAY ASSOCIATIONS

Study of association between pairs of Collembolan species, pairs of fungal genera, pairs of bacteria / actinomycetes genera pairs of collembolan and fungal forms, pairs of collembolan and bacteria / actinomycetes forms pairs of fungal and bacteria / actinomycetes forms have counted by means of Two Way Frequency tables in each site separately. The association between the Collembola, fungi and bacteria / actinomycetes with different edaphic factor and heavy metals were also analyzed statistically. The significant result of these tests was shown in the table 4. In the study site, two pairs of Collembola were found to have significant association in Collembolan community, in between second *(X. obscura)* and fifth *(Cryptopygus thermpphilus)* dominant species. (Table 4). In the present site, the most predominant form of Collembola *(L. cyaneus)* showed significant association with the most predominant forms of fungi *(Penicillum)* and first second dominant forms of bacteria / actinomycetes *(Bacillium* and *Streptomyces).* The site specific of Collembola P. *(Clavisotoma) fitchioides* and second dominant fungi (*Aspergillus*) exhibited significant association. In bacteria-actionmycetes community two site-specific bacterial strains (*E. coli*, *Corynebacterium)* showed significant association with each other. Table 4 revealed significant association of *C. javanus* and *P.* (Clavisotoma) *fitchioides* with Cu, of *L. cyaneus* and *Penicillium* with Zn and between *Micrococcus* and Hg.

Table 4 : Analysis of Two – way Frequency tables

Frequency Table I

Penicillum	**0**	**1**	***L. cyaneus*** **6.5**	**20.75**	**Last**	**Total**
0	0	0	0	0	0	0
16	0	2	1	5	0	8
25	0	4	2	2	0	8
34.25	0	3	2	1	1	7
LAST	0	1	0	0	6	7
TOTAL	0	10	5	8	7	30

Measures of Association : PROB = 0.0022

Frequency Table II

Bacillus	**0**	**1**	***L. cyaneus*** **6.5**	**20.75**	**Last**	**Total**
0	0	0	0	0	0	0
32	0	3	3	1	0	7
55.5	0	0	1	6	1	8
18.25	0	2	1	0	5	8
LAST	0	5	0	1	1	7
TOTAL	0	10	5	8	7	30

Measures of Association : PROB = 0.001

Frequency Table III

Streptomyces	0	1	*L. cyaneus* 6.5	20.75	Last	Total
0	0	0	0	0	0	0
5	0	6	0	2	0	8
12	0	1	2	3	2	8
16.25	0	0	0	3	4	7
LAST	0	3	3	0	1	7
TOTAL	0	10	5	8	7	30

Measures of Association : PROB = 0.0092

Frequency Table IV

Zinc	0	1	L. *cyaneus* 6.5	20.75	Last	Total
515	0	0	1	1	6	8
550	0	4	0	5	0	9
600	0	3	2	2	0	7
LAST	0	3	2	0	1	6
TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0031

Frequency Table V

Archerontiella	0	5	*Calx sp* 11	12.75	Last	Total
0	26	1	0	0	0	27
1	2	0	0	0	0	2
2	0	0	0	0	1	1
LAST	0	0	0	0	0	0
TOTAL	28	1	0	0	1	30

Measure of Association : PROB = 0

Frequency Table VI

Copper	0	*Cyphoderus javanus* 2	9.5	74.75	Last	Total
180	0	5	1	3	1	10
157.5	0	1	1	0	3	5
205	0	3	3	4	2	12
LAST	0	1	0	1	1	3
TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0045

Frequency Table VII

Xenylla obscura	0	*Crptopygus thermophilus* 2	3	17.5	Last	Total
0	9	0	0	1	0	10
18.5	0	4	0	1	0	5
63	1	3	0	1	0	5
104.5	0	1	1	1	2	5
LAST	0	1	1	0	3	5
TOTAL	10	9	2	4	5	30

Measure of Association : PROB = 0.0008

Frequency Table VIII

Aspergillus	0	P. *(Clavisotoma) fitchioides* 1.5	11	16.5	Last	Total
0	0	0	0	0	0	0
2.75	6	1	0	0	0	7
5	11	0	0	0	0	11
9	4	0	2	1	0	7
LAST	1	1	0	1	2	5
TOTAL	22	2	2	2	2	30

Measure of Association : PROB = 0.0099

Frequency Table IX

Copper	0	*P. (Clavisotoma) fitchioides* 1.5	11	16.5	Last	Total
0	9	1	0	0	0	10
197.5	3	0	2	0	0	5
205	9	1	0	0	2	12
LAST	1	0	0	2	0	3
TOTAL	22	2	2	2	2	30

Measure of Association : PROB = 0.001

Frequency Table X

Zinc	**0**	***P. (Clavisotoma) fitchioides*** **1.5**	**11**	**16.5**	**Last**	**Total**
0	9	1	0	0	0	10
197.5	3	0	2	0	0	5
205	9	1	0	0	2	12
LAST	1	0	0	2	0	3
TOTAL	22	2	2	2	2	30

Measure of Association : PROB = 0.0038

Frequency Table XI

Murcury	**0**	***Micrococus*** **8**	**17**	**26**	**Last**	**Total**
0.66	2	0	0	4	2	8
1	4	3	1	0	1	9
1.3	4	1	2	0	0	7
LAST	6	0	0	0	0	6
TOTAL	16	4	3	4	3	30

Measure of Association PROB = 0.0097

Frequency Table XII

Corynebacterium	**0**	***E. coli*** **3**	**7**	**10**	**Last**	**Total**
0	21	1	1	0	0	23
2	2	0	0	0	0	2
4	2	0	0	0	0	20
13	2	0	0	0	0	2
LAST	0	0	0	1	0	1
TOTAL	27	1	1	1	0	30

Measure of Association: PROB = 0.0023

DISCUSSION

The present investigations were based on the sample survey of 6 plots from the reclaimed wetland embankment of Kolkata over a period of 30 months (January 2003 to June 2005). The site was in Gangetic plains exposed to tropical climate with humidity and temperature; these two factors were comparatively low during winter months. The collembolan fauna obtained here, belonged to 16 genera of the families Hypogastruridae, Isotomidae, Entomobryidae and Sminthuridae. Only 17 species of Collembola were found to occur in this habitat. Fungal population studied belonged to 8 genera and the bacterial-actinomycetes community comprised of 10 genera. The total populations of collembola fauna obtained from the sampling sites in the present study showed numerically vary with the change of season. It was minimum in May and maximum in March. A low summer population of Collembola agreed with the general experience of this group as reported from different types of field of West Bengal by numerous workers like Hazra and Choudhuri, (1990); Hazra and Sanyal (1996). The population maximum in March in the present study site with minimum population in May was similar observation of Mukherjee and Singh (1970) at Varanasi Rose garden gangetic plane of India.

The study of association of collembolans with the soil micro-organisms specially with the feeding preference of Collembola for fungal hyphae and spore has previously recorded by several workers, viz. Waksman (1916 and 17), Bellinger (1954), Tadros and Verney (1983), Klironomos *et al.* (1992) and Pal *et al.* (1992), but the study of relationship within Collembola and soil bacterial community are fragmentary, specially, in field condition and constructive study has not been done so far specially in India on the aspect. Hazra and Bhattacharyya (2003) studied of Collembola from agricultural fields and waste disposal sites of West Bengal with special reference to their microbial association.

In this study, the underground microbial community encountered belongs to 8 fungal genera, 10 bacterial-actinomycetes genera (Table 1d and 1e). The abundance of these forms was varied from one site to other and from season to season. The density of most of the dominant taxa in microbial flora generally took remarkable changes throughout the year in which one or two outstanding maxima and minima occurred. Of the 8 fungal genera the predominant forms were *Penicillium, Asperagillus* and *Fusarium* mentioned in order of dominance.

It is evident from the figure 1i that in total bacteria-actinomycetes community the bacterial genus *Bacillus* out numbered all the other forms followed by *Streptomyces, Arthrobactor and Mucor.*

As to the role of edaphic factors on the distribution and population pattern of different groups of soil inhabiting micro fauna and flora, it might be assumed that the factors analyzed in this study exerted both significant and non significant affects either singly or in a cumulative way. Collembola and fungi population showed positive correlation with temperature which is coincided with the earlier study Mitra et al (1977) and Bhattacharya and Roychoudhuri (1979).

The value of correlation of Collembola and moisture was significant in the present study. Hazra and Choudhuri (1983, 90) and Guru *et al.* (1988) found positive non significant correlation between soil organism and moisture (Table 2).

The content of organic carbon varied between 3.2 % to 4.23 % (table 1a) and exhibited strong positive correlation with the population density of soil fauna and flora.

Another important driving variable affecting the population fluctuation of soil biota was the soil pH which varied between 5.08 to 6.9. The statistical analysis showed strong negative correlation with the population of all the groups studied and one highly significant with Collembola and fungal population. This was in agreement with the finding of Agrell (1941), Bellinger (1954), Choudhuri *et al.* (1978) ~~and~~ Pal *et al.* (1992).

Nitrate content of the soil was maximum 3.13 ppm and minimum 2.7 ppm the analysis of correlation coefficient revealed positive and significant correlation in most cases with the populations of all the three groups studied here.

In the present investigation value phosphate content of the soil measured maximum 14.6 and the mean value of phosphate was 10.59 ppm. The analysis of correlation coefficient showed positive with population of soil organisms considered. Hazra (1976) found either weak or negative correlation with Collembola population.

Among the heavy metals content in soil Cd, Cu and Pb are the most thoroughly investigated metals; fewer data are available for Hg, Zn, Ni and Cr. Among the soil animals most data concern earthworms, followed by slug and springtails. In this investigation a simple comparative approach was made to demonstrate the impact of heavy metals like Hg, Cu, Pb and Zn on the collembolan population characteristics i.e., species composition, species richness, abundance and distribution in different habitats in association with soil bacteria-actinomycetes and fungi by correlation study. But, on point in particular is that, it is very difficult to evaluate the impact of single heavy metal on the soil mesofauna or flora.

The concentration levels of heavy metals in the soil considered in the present study showed wide range of variation from 0.5 ppm to 4.2 ppm mercury, 20 ppm to 210 ppm copper, 130 ppm to 300 ppm lead and 495 ppm to 615 ppm zinc (Table 1b).

The population of micro flora and fauna were found to be maximum when the concentration levels of heavy metals (especially Hg, Pb and Zn) were significantly low and minimum in summer months when the levels of heavy metals were high. The present site is situated by the site of Eastern Metropolitan Bypass at Kolkata and main source of heavy metals in the soil may be the garbage material dumped by Kolkata Municipal Corporation. In the present study site the highest concentration levels of all the heavy metals were recorded and supported the maximum population densities of soil micro flora and fauna. In this study site high concentration of nitrate showed direct correlation with maximum population of Collembola. This might be due to the fact as stated by Bengtsson and Tranvik (1983) that with nitrogen rich food source the cost of increased moulting frequency which resulted in slow growth seemed to be compensated and a high growth rate maintained even in a polluted environment.

The species composition in bacterial population encountered from the present study site was dominated by gram positive taxa *Bacillus* (28% of total population) and among the other forms *Micrococcus* (3.66%), *Cytophaga* (3.25%), *Promicromonospora* (1.32%), *Corynrbacterium* (0.98%), *Pseudomonas* (0.67%) and *E. coli* (0.3%) were abundant (Table 1c). Mahler et al. (1986) found many gram positive spore formers resistant to Hg and Cd. However, in contrast to this finding Doelman and Haanstra (1979c), Bath (1989) and Tyler *et al.* (1989) reported gram positive taxa o be more sensitive to heavy metals than gram negative, Duxbury and Bicknell (1983) isolated the metal tolerant bacterial population from natural and metal polluted soils and found the rod shaped gram negative bacteria in maximum numbers. Tayler et al. (1989) and Baath (1989) suggested that a more sensitive approach to detect heavy metal effects as microorganisms might be to estimate the number of tolerant instead of total number of organisms.

It may be difficult or sometimes impossible to define a 'critical' concentration or degree of population at which noxious effects of heavy metals on organisms or ecosystem do appear (Tyler *et al.*. 1989). According to Bengtsson *et al.* (1983) high concentration of metals seem to be necessary for significant reduction of population density.

The results of this investigation mostly corroborated those of other workers (cited above) while in certain aspects they showed striking difference from those reported earlier. This might be due to the prevalence of local environmental factors which were likely to exert profound influence in the pattern of population structure (Wall work, 1970).

SUMMARY

Present studies contain results of an ecological study involving the impact of different factors and some heavy metal pollutants on subterranean collembolan population and association with the soil microbes (Fungi and bacteria actinomycetes population) in reclaimed wetland embankment of Kolkata, West Bengal. Soil factors like temperature, moisture, pH, organic carbon, nitrate and phosphate and heavy metals such as mercury, copper, lead and zinc were taken into consideration. Fungi and bacteria-actinomycetes population and their interactions with these parameters and soil fauna were also studied. All these were found to vary seasonally. A total of 270 soil samples were drawn from various plots at monthly intervals in a period of thirty months (January 2003 to June 2005). Population density of total Collembola, fungi and bacteria-actinomycetes in order of abundance were 60.50%, 31.8% and 47.38% respectively at this site. The collembolan fauna encountered, belonged to17 species under 16 genera of the families Hypogastruidae Isotomidae, Entomobryidae and Sminthuridae. Fungal population studied belonged to 8 genera and the bacterial-actinomycetes community comprised of 10 genera. Numerically the genus *Lepidocyrtus* occupied topmost position among all the collembolans and was widely distributed, *Xenylla* and *Cyphoderus* respectively occupied second and third position, and the other genera like *Isotomurus, Homidia, Salina, Cryptopygus, Yosiia, Sminthurides, Seira, Isotomiella* mentioned in order of dominance. Populations of most of the other genera were numerically low and irregular

in distribution pattern. In order of dominance the *Penicillium* and the *Bacillus* occupied topmost position among the fungal and bacteria-actinomycetes communities respectively. The peak population of Collembola and fungi found to be coincided during March. However, the bacterial population peak varied from one year to another year of observation, which was found to be coincided with the collembolan / fungal population in this study site. The correlation between the populations of Collembola, fungi with that of bacteria-actinomycetes were positively significantly correlated this study site. Of the soil factors *viz.* moisture, organic carbon, nitrate and phosphate also showed positive significant correlation with Collembola, fungi and bacteria-actinomycetes population. The heavy metals like mercury, lead and zinc exhibited negative correlation with the total population of Collembola as well as fungi / bacteria-actinomycetes populations. The measure of association broadly indicates more significant values in the- complex biotic communities in soil *(viz.* between pairs of different genera / species of Collembola / fungi / bacteria-actinomycetes) at study site. From the present investigation it might be inferred that the effect of mechanical disturbances due to poor soil environment and dumping of municipal wastes (household refuses / industrial discharges) on soil surface which cause soil environment polluted and results to the reduction of the soil micro fauna / flora quantitatively or qualitatively. Thus, the reduction of these active biological agents the process of soil formation would become slow with the ultimate effects on soil health in general.

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PLATE-1

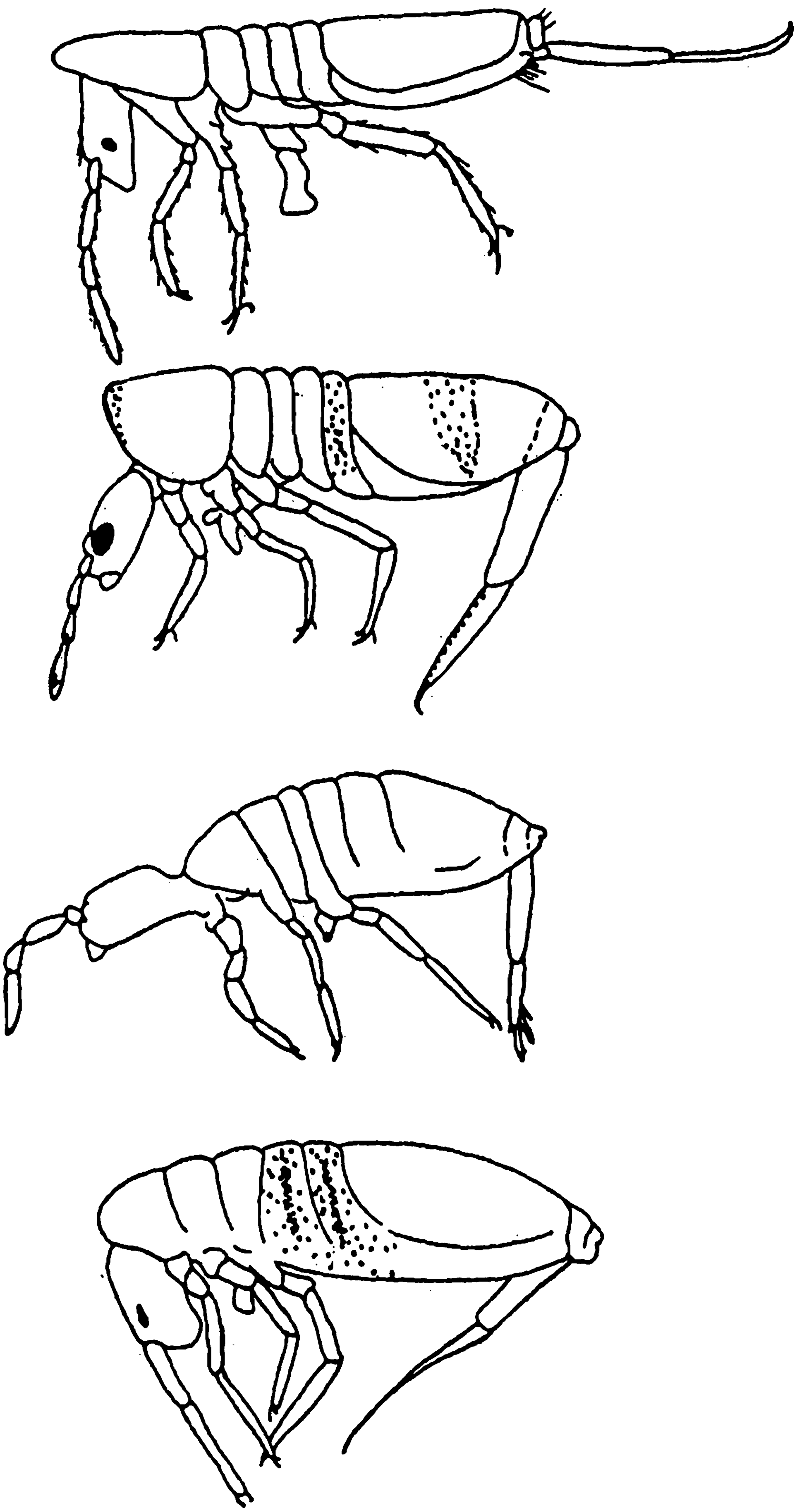
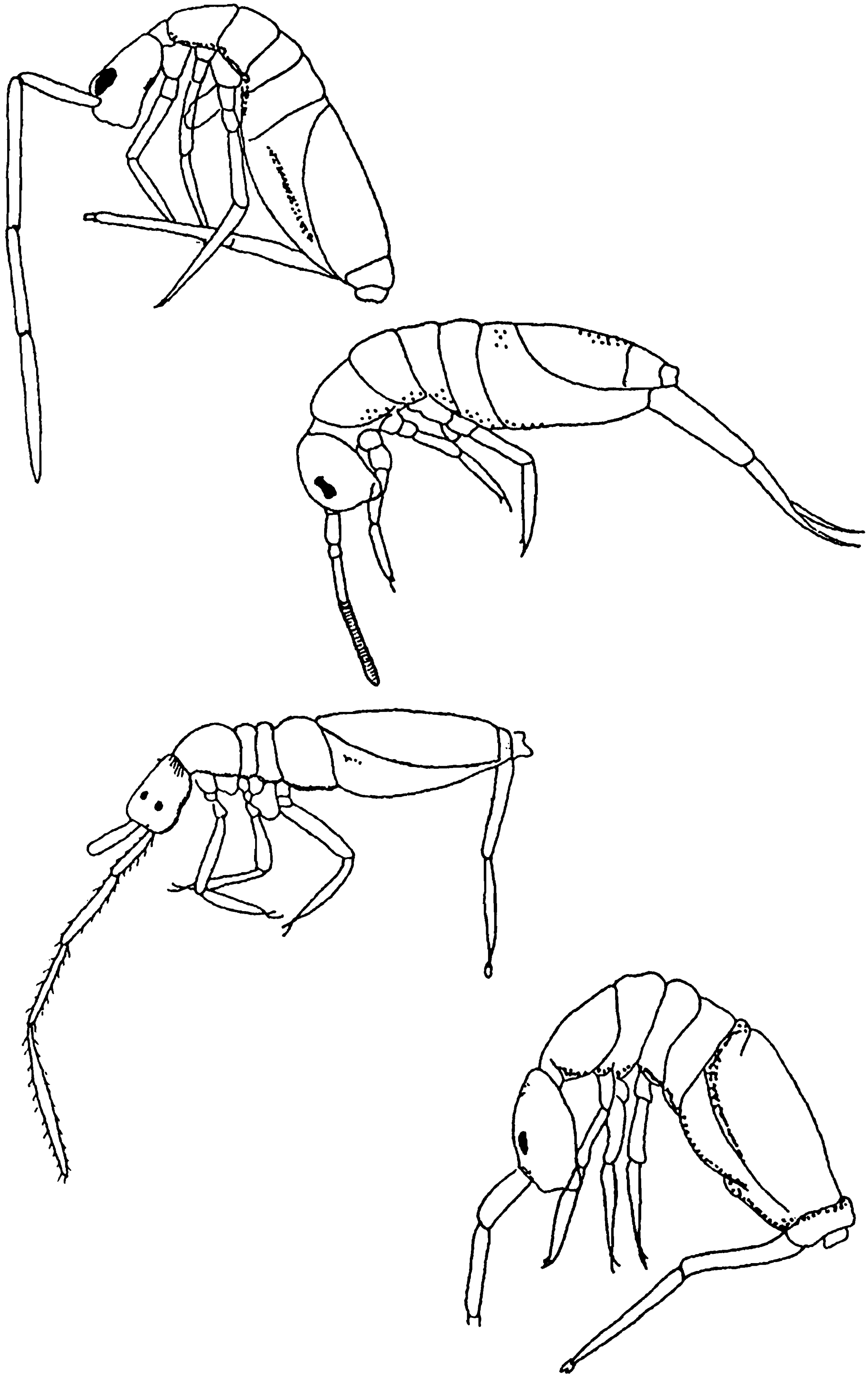


PLATE-2



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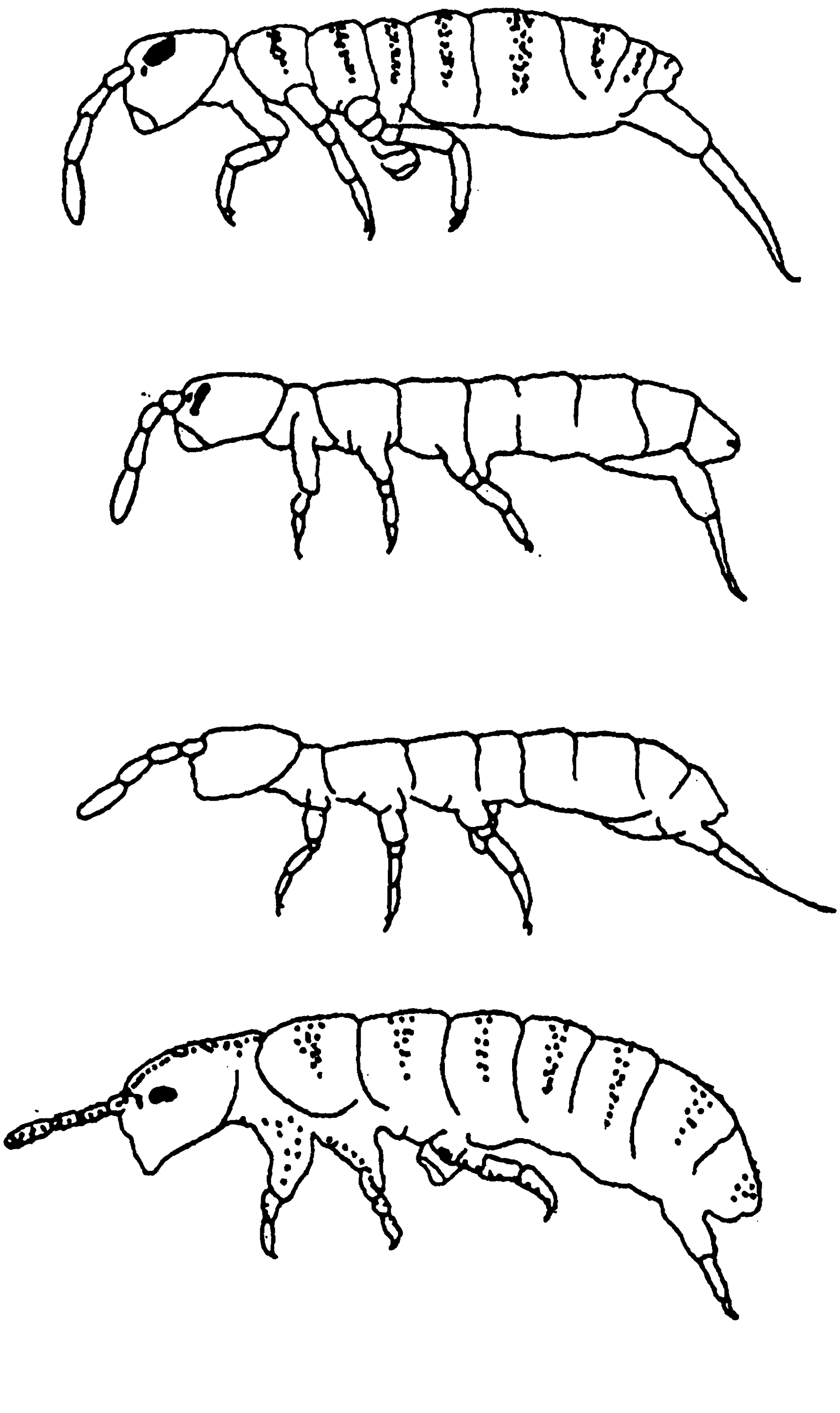

PLATE-4

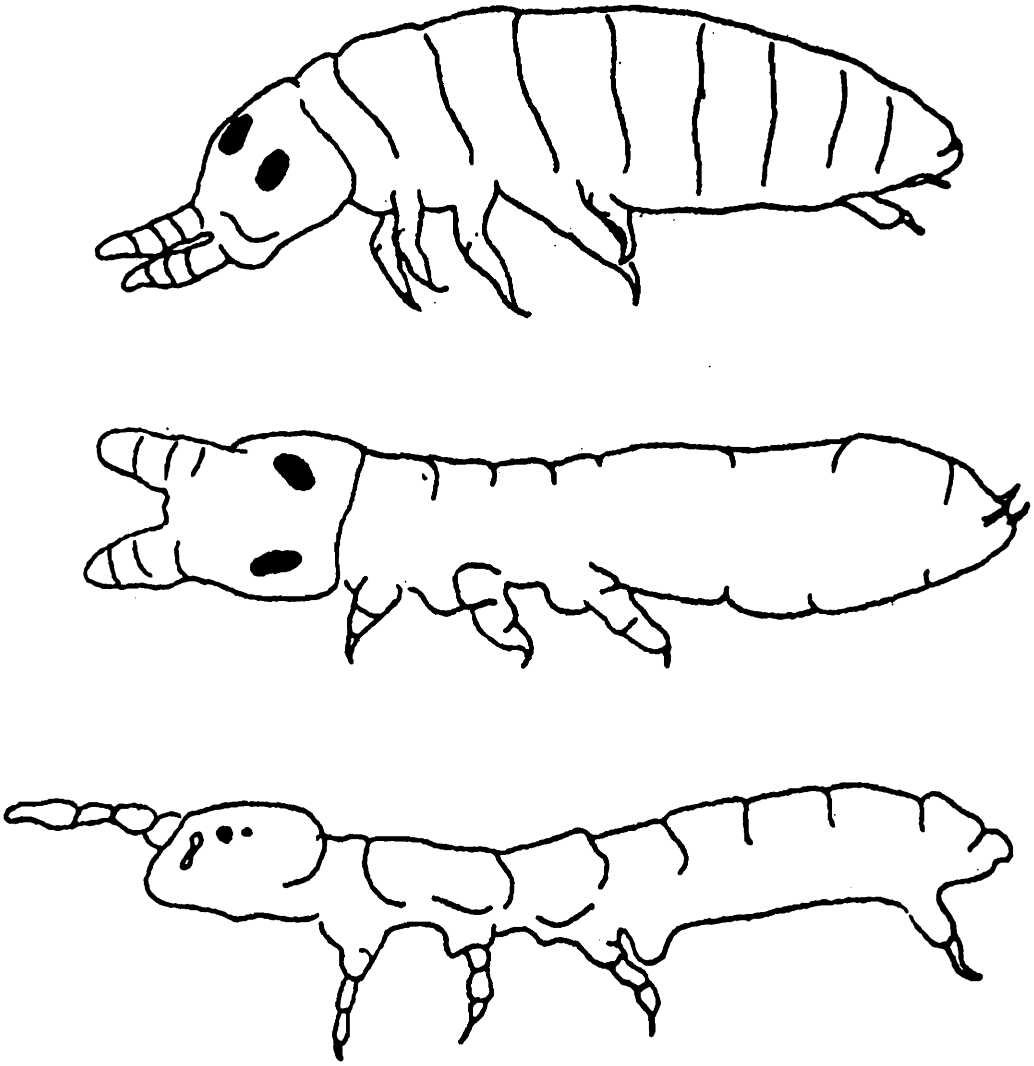

Plate 1-4 : Out line diagrams of collembolans (viz., *Lepidocyrtus cyanus, Xenylla obscura* , *Cyphoderus javanus, Seira indica, Cryptopygus thermophilus, Friesea yosii, Proisotoma (Clavistoma) fitchioides, I. exploratorius, Ballistrura bengalensis, Calx sp., Isotomurus balteatus, I. heterolepis, Archerontiella sp, Isotomiella sp, Willemia sp)* found in the sampling site at Dhapa, Kolkata.

Photo 1 & 2. : Sampling sites at Dhapa, Kolkata.