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Earthworm Distribution with Special Reference to Physicochemical Parameters

S R GANIHAR
Department of Zoology, Dhempe College of Arts &Science, Miramar, Panaji 403 001

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Earthworm distribution with special reference to physico chemical parameters of soil studied at fifteen locations on three occasions (July, Sept. 1992 and July 1993) yielded sixteen species of earthworms, which adds twelve species to ZSI list of this area (Goa). The study also revealed that species richness (no. sp/m^2), density (no/m^2) and wet biomass (live wt.g/m^2) of the earthworms were significantly related with physicochemical parameters viz., atmospheric temperature, soil *p*H ($p < .05$); soil temperature, moisture, water holding capacity, organic matter, exchangeable calcium, magnesium, phosphorus and inorganic nitrogen ($p < .01$) of soil in which they inhabit. The importance of physicochemical parameters in earthworm distribution is discussed.

Key Words: Earthworms, Distribution, Goa, Physicochemical parameters

Introduction

The distribution of Earthworms not only depends on physicochemical factors of the soil but also their reproductive potential and dispersive power (Edwards & Lofty 1977). The information on the ecology of earthworms from natural ecosystems of Indian tropics is limited (Bhadauria & Ramakrishnan 1991), however, there are some comprehensive faunastic studies on earthworms in India (e.g. Dash & Patra 1977, Kale & Krishnamoorthy 1978, 1981, Reddy & Alfred 1978, Senapati et al. 1979, Julka & Mukherjee 1984, Ismail & Murthy 1985, Krishnamoorthy & Ramachandran 1988, Mishra & Ramakrishnan 1988, Mishra & Ramakrishnan 1988, Ismail et al. 1990 and Bhadauria & Ramakrishnan 1989, 1991). These studies showed the influence of various edaphic factors viz; temperature, moisture, water-holding capacity, organic matter, *p*H and mineral nutrients etc. on the population size of earthworms.

No studies on the earthworm distribution of Goa are available except for two taxonomic studies (Stephenson 1923, Soota & Julka 1977). An attempt is made in the present study to investigate the distribution of earthworms in the soils of north Goa correlating their distribution to physico-chemical factors of soils they inhabit. The factors studied were atmospheric temperature, soil-temperature, soil moisture, maximum water holding capacity, *p*H, organic matter, exchangeable calcium, magnesium, phosphorus, and inorganic nitrogen.

Study Area and Methods

Climate

The state of Goa lies between the north latitudes 14°48′-15°52′ and east longitudes 73°38′-74°24′ and it has three months of spring and summer (March-May), four months of south-west monsoon (June-September), two months of autumn (October & November) and three months of winter (December-February). The atmospheric temperature varies between 28-34°C (maximum) and 20-27°C (minimum) (34°C in May, 20°C in winter). The maximum and minimum annual values of relative humidity vary between 83-94% and 70-92% respectively. Both the values will be maximum during monsoon months due to moisture laden winds. The high content of the relative humidity prevailing in Goa almost throughout the year which is a typical coastal feature most part of the rainfall occurs from June to September during South-West monsoon season, the average rainfall varying from 3000 mm per year in coastal areas to 3750 mm per year in the hilly regions.

Location

Earthworm study was conducted at fifteen locations and they designated as 1-15 (seven locations nos. 7,8,11,12,13, 14 & 15 were of forest habitat in mountain regions and these mountains are the parts of Western Ghats covered with semievergreen forests, remaining eight were at coastal region, four each nos. 1,2,4 & 6 and nos. 3,5,9 & 10 were of Garden soil and waste land habitat respectively. The waste land habitat are covered with scrub forest). The locations 1-6 were located in and around the city of Panaji, each one is atleast 1-3 km. away from the other. The locations nos. 7-15 are located outside the Panaji city at north Goa district. The soil types vary from heavy sand (coastal) to clay loam (Ghats) the parent material being of laterite origin.

Location 1 (at Dhempe College campus at Miramar): The main tree species are *Tamarindus indica, Albizzia lebbeck, Anacardium occidentale, Casuarina equisetifolia, Eucalyptus commaldensis.*

Location 2 (at Tonca—a private land): The main tree species is *Mangifera indica.*

Location 3 (adjacent to a small stream at St. Inez): The main tree species are *Ficuss bengalensis* and *Mangifera indica.*

Location 4 (at Taleigao): Tree species are *Mangifera indica* and *Cocas nucifera.*

Location 5 (adjacent to the football ground at Caranzalem): The main tree species is *Tamarindus indica.*

Location 6 (Campal) : Tree species *Acacia arabica.*

Location 7 (at Tivim): tree species *Strychrous Nux-vomica, Careya arborea, Carissa caranda, Amorphophyllus commutatus, Curcuma* sp., *Smilax zeylania* and *Dioscorea bulbifera.*

Location 8 (at Mulgao): Plant species are *Ficus bengalensis, Zanthoxylum Rhetsa, Ixora coccinea, Clerodendron infortunatum.*

Location 9 (at Sirsaim): *Tree species Acacia auriculiformis.*

Location 10 (at Mayem): adjacent to the heaps of iron ore mine rejects plant species *Grewia tilaefolia* and grass.

Location 11 (adjacent to state transport road at Bainginium-Old Goa): The main tree species *Tectona grandis.*

Location 12 (at Veling): adjacent to Mardol town tree species: *Araca catacha, Careya arborea Zanthoxylum, Rhetsa, Ficus bengalensis* and *Artocarpus integrifolia.*

Location 13 (Khandepar): adjacent to the river Khandepar. Plant *Cocas nucifera* (Sacordem)

Location 14 species : adjacent to state transport road and is inhabited by plant species *Glyricida macrulata, Ixora coccinea, Calycopteris floribanda* and *Grewia tiliaefolia.*

Location 15 (at Molem) adjacent to national highway: The main floral components are *Garcinia indica, Carissa caranda, Terminalia tomentosa.*

Methods

Sampling of Earthworm Populations

Samples were collected at random from

quadrats, each quadrat (1m × 1m × 30cm) covering a soil volume of 0.3 m^3. From each location total ten quadrats were sampled (three each in July & September 1992 and four in July 1993). Each sample unit was dug down to the depth of 30 cm. The earthworms were handsorted (Lewis & Taylor 1967) on plastic sheet and collected in polythene bags and brought to the laboratory. Wet biomass (live wt.g/m^2), species richness (nos. sp/m^2) and density (nos/m^2) were estimated. All the specimens were preserved in 5% formaldehyde. The specimens were identified upto species level according to Stephenson (1923) and Julka (1988) the identification were later confirmed by Dr. J.M. Julka.

Atmospheric temperature (45 cm above soil level), soil temperature (10 cm below soil level) were recorded for each locality during earthworm collection. The soil samples were also collected for the physicochemical analyses.

Soil Analysis

Soil *p*H was measured by electrometrically in a solution by using distilled water (1 g in 20 ml). Soil moisture content was estimated by keeping fresh soil samples in an oven drying at 105°C until constant weight. Water holding capacity was measured by using sintered crucibles filled with oven dried and sieved through 2 mm mesh soil samples kept over a container filled with water and kept for 24 hr. The soil organic matter was determined as loss-on-ignition of oven dry soil over 24 hr. in a muffle furnace at 550°C (Allen et al. 1976). Exchangeable mineral nutrients from soil were estimated viz; phosphorus measured colorimetrically by molybdenum blue method, after extraction with Trough's reagent. Exchangeable calcium and magnesium were estimated by EDTA titration methods after extraction with HNO_3 as detailed in Allen et al. (1976). Inorganic nitrogen (ammonium nitrogen) was estimated by Microkjeldahl alkaline permanganate method as detailed in Perur (1972).

Statistical Treatment

The regression (r) between soil parameters and earthworm parameters was calculated as simple correlation coefficient and the test of significance for (r) was calculated by using $t = r \sqrt{n-2/1-r^2}$

Results and Discussion

A total of 16 species, 8 genera, 4 families, 2 orders of class oligochaeta were collected. Among them nine species were from family octochaetoidae, 3 species each from Megascolecidae and Moniligastridae and one species from Glossoscolidae (table 1). Five species were from genus *Hoplochaetella* which were abundant and they are endemic to this area (Julka 1988), the species which are also very common in their distribution viz; *Drawida travancorensis* (Michaelson), *D. kanarensis* (Stephenson), *Megascolex konkanensis* (Fedarb) and *Pontoscolex corethrurus* (Muller).

Location 12 had the largest earthworm populations in terms of species richness, density and biomass whereas, Location 10 was poor (table 2).

A number of ecological factors often inter-correlated, are known to play a vital role in the distribution and abundance of earthworms. The most important among them are temperature, moisture, water holding capacity, organic matter and Hydrogen ion concentration.

The mean values of temperatures recorded during the study varied between 25.56°C (Location 12) to 30.55°C (Location 10) with mean $\bar{x}$ = 28.41 ± 0.43 SE (atmospheric temperature) and between 24.44°C (Location 12) to 29.44°C (Location 10) with mean $\bar{x}$ = 27.22°C ± 0.46 SE (soil temperature). Atmospheric

Table 1 *Earthworm species composition and mean values ± S.E. (Standard error) of parameters investigated at different locations during study*

Location	Species composition	Species richness nos. sp/m²	Density nos/m²	Wet Biomass g. live wt/m²	Moisture %	Water holding capacity %
1	2	3	4	5	6	7
1. Miramar	Dk, Ds, Meh	2.3±0.21	73.00±3.73	38.56±1.19	22.34±0.55	57.20±1.32
2. Tonca	Ds, Pc, Mk	2.4±0.22	83.00±2.92	42.62±2.01	22.84±1.25	60.39±1.73
3. St. Inez	Ds, Pc, Mh	2.1±0.23	68.00±2.43	29.36±1.57	21.32±1.09	54.22±0.81
4. Taleigao	Mh, Mk, Ha	2.2±0.20	70.00±3.09	35.00±2.59	21.42±1.24	55.78±0.64
5. Caranzalem	Mk, Pc, Mh	2.4±0.16	85.50±2.29	43.05±2.33	23.24±0.68	60.15±2.57
6. Campal	Dt, Hs, Mh	2.3±0.21	73.45±2.22	41.32±1.33	22.29±0.70	58.37±1.77
7. Tivim	Ek, Hsu, Mh	2.4±0.22	90.00±3.29	45.68±1.54	24.02±0.44	62.11±1.12
8. Mulgao	Ek, Haf, Hsu	2.55±0.16	86.00±3.10	43.68±1.80	23.52±0.90	61.10±1.47
9. Mayem	Ds, Oc	1.8±0.13	56.00±1.59	21.56±1.55	17.21±0.50	50.23±1.61
10. Sirsaim	Dt, Dk	1.6±0.16	24.33±0.55	19.72±1.40	17.00±0.32	50.10±1.44
11. Bainguinim	Hsp. Hsa	1.9±0.10	61.50±1.75	29.04±1.26	21.20±1.15	54.26±0.99
12. Veling	Dt, Pc, Haf, Hsu, Ot, Mh	3.8±0.29	102.20±1.73	86.00±0.79	25.10±1.01	62.22±1.45
13. Khandepar	Mk, Ot	1.7±0.17	40.00±2.94	24.96±0.63	18.34±0.62	54.00±1.22
14. Sacordem	Db, Mh, Hsa	1.9±0.23	64.00±2.55	28.43±1.35	20.50±1.06	53.10±1.18
15. Molem	Dbv, Oc	1.7±0.15	55.50±1.43	26.38±1.65	20.12±0.89	51.10±1.83

Location	Organic matter %	pH	Exchangeable mg/100g			
			Calcium	Magnesium	Phosphorus	Inorganic nitrogen
	8	9	10	11	12	13
1. Miramar	9.32±0 .69	6.53±0.07	240±12.72	857±23.23	59±2.15	40±1.92
2. Tonca	9.46±0.44	6.54±0.06	300±7.15	966±30.80	60±6.73	31±2.42
3. St. Inez	8.53±0.39	6.5±0.10	200±9.29	804±31.39	58±1.3	35±0.69
4. Taleigao	8.52±0.34	6.53±0.1	220±5.82	852±31.49	59±2.08	30±0.73
5. Caranzalem	9.36±0.36	6.5±0.10	250±9.92	964±29.84	62±1.62	42±1.6
6. Campal	10.21±0.49	6.53±0.07	245±9.5	974±27.25	59±1.39	35±0.66
7. Tivim	10.22±0.56	6.85±0.11	250±9.02	1003±27.15	62±1.35	53±1.48
8. Mulgao	12.64±0.39	6.8±0.11	300±27.02	1012±26.84	62±2.13	48±1.42
9. Mayem	6.03±0.35	6.05±0.17	200±5.22	663±23.49	49±1.69	28±1.09
10. Sirsaim	7.30±0.49	6.05±0.13	80±3.25	688±18.59	56±1.16	26±1.05
11. Bainguinim	7.08±0.36	6.5±0.14	180±15.05	652±22.07	54±2.28	23±0.88
12. Veling	13.56±0.62	7.0±0.13	300±10.06	1072±35.86	68±1.93	60±1.44
13. Khandepar	7.85±0.38	6.54±0.07	120±4.19	655±16.54	57±1.86	22±0.61
14. Sacordem	7.21±0.31	6.52±0.06	238±12.6	659±18.20	53±1.9	26±0.9
15. Molem	8.28±0.35	6.51±0.14	120±5.61	726±29.27	58±1.67	22±1.06

Dk, *Drawida kanarensis* (Stephenson); Dt, *D. travancorensis* (Michaelson); Ds, Drawida spp. (Moniligastridae; Moniligastrida); Ps, *Pontoscolex corethrurus* (Muller) (Glossoscolecidae; Haplotaxida); Db, *Dichogaster bolaui*; (Michaelson); Ek, *Eudichogaster kinneri*; (*Michaelson*); *Haf, Hoplochaetalla affinis* (Stephenson); Ha, *Haplochatella anomalus* (Stephenson); Hsu, *Haplochaetella suctoria* (Stephenson); Hs, *Hoplochaetella sanvordemensis* (*Julka*); *Hsp, Hoplochaetella* spp; Oc, *Octochaetus castellanus* (Stephenson); Ot, *Octachaetus thurstoni* (Michaelson) (Octochaetidae; Haplotaxida); Mn, *Megascolex hortonensis* (Stephenson), Mk, *Megascolex konkanensis* (Fedarb) and Meh, *Metaphire houlleti* (Perrier) (Megascolecidae; Haplotaxida)

Table 2 *Correlation coefficients (r) for soil parameters and earthworm parameters*

	Atmospheric temp.	Soil temp.	Moisture	Water holding capacity	*p*H	Organic matter	Calcium	Magnesium	Phosphorus	Nitrogen
Species richness	−0.73	−0.78	0.82	0.80	0.73	0.87	0.76	0.82	0.77	0.87
Density										
Wet	−0.75	−0.81	0.94	0.88	0.75	0. 76	0.91	0.85	0.70	0.82
biomass	−0.71	−0.77	0.82	0.80	0.72	0.87	0.71	0.81	0.84	0.85

0.70 - 0.75 = $p < .05$, 0.76 - 0.95 = $p < .01$

temperature ($p < .05$) and soil temperature ($p < .01$) showed significant negative correlation to the distribution of earthworms (table 2). These findings corroborate those of Senapati and Dash (1983) and Ismail and Murthy (1985).

Temperature largely effects earthworm activity. Compared to temperate species tropical species can withstand higher temperature (Edwards & Lofty 1977, Lee 1985). The species *Drawida kanarensis*, *D. travancorensis*, and *Octochaetus thurstoni* appears to be tolerant to the higher temperature upto 30°C (present study). Similarly, Ismail and Murthy (1985) observed tolerance of *Lampito mauritii* (Kinberg) to higher temperature range (30 ± 2°C) at Madras.

Soil moisture varied between 17% (Location 10) to 25% (Location 12) (table 2) and it showed significant positive correlation to earthworm distribution (species richness, density and biomass (table 3). Earthworm activity peaked during the rainy season an observation also reported by others Ismail and Murthy (1985), Dash and Patra (1977), Reddy and Alfred (1978), Julka and Mukherjee (1984).

Maximum water holding capacity is an important factor which indirectly indicates the soil texture. The values varied from 50% (Location 9) to 62% (Location 12) and it was significantly related with earthworm distribution. Table 2 indicating that soils with good water holding capacity allow the earthworms to burrow. The burrowing activity alter the water holding capacity to a large extent, this has been observed by Ismail and Murthy (1985), Ismail et al. (1990). However, Nordstrom and Rundgren (1974) printed out that there is an indirect relationship as the colloidal nature of clay which is important for water holding capacity is interrelated with other edaptic factors which are also important for earthworms activity. This is further confirmed by Christensen and Mather (1990).

Organic matter constitutes the source of food for earthworms influences their distribution; soils with low organic matter do not support earthworm population (Edwards & Lofty 1977). The mean value of organic matter content varied greatly from 6.03% (Location 9) to 13.56% (Location 12) (table 1). The Location 12 (Veling) which is enriched with organic matter, at an optimal condition of temperature and moisture supports a high density ($102/m^2$) and species richness ($3.8/m^2$) and fresh biomass ($86\ g/m^2$). Species recorded here include *Drawida travancorensis*, *Pontoscolex corethrurus*, *Haplochaetella affinis*, *H. suctoria*, *Octochaetus thurstoni* and *Megascolex hortonensis*. The organic matter content of the soil showed significantly positive to earthworm distribution. This is in agreement with the results of several earlier studies (e.g. Ismail & Murthy 1985, Krishnamoorthy & Ramachandra 1988, Mishra & Ramakrishnan 1988, Krishnamoorthy 1989, and Bhadauria & Ramakrishnan 1991).

Soil *p*H in the locations varied slightly acidic (*p*H 6.05 at Location 10) to neutral (*p*H 7.0 at Location 12) (table 1). Edwards and Lofty (1977) suggest that earthworm species generally have narrow range in *p*H, very few being restrictive to highly acidic soils (*p*H < 4). Most of them prefer neutral soils, but some can tolerate acidic or alkaline soils. The *p*H values recorded in the present study are within the preferred range for the distribution of earthworm and it showed positive correlation to earthworm distribution (table 2), similar observations are also made by Ismail and Murthy (1985), Krishnamoorthy (1989), Ismail et al. (1990), Bhadauria and Ramakrishnan (1991).

Greater variations in the mean values of exchangeable cations of Calcium (80-300 mg/100 g. of soil), magnesium (652-1072 mg/100 g.), phosphorus (53-68 mg/100 g.) and inorganic nitrogen (22-60 mg/100 g.) were observed in study locations (table 1). These mineral nutrients showed significant positive correlation with earthworm distribution (table 2), which indicated the positive role of earthworms in the process of mineralization. Several studies showed the effect of earthworms on available mineral nutrients and documents that soils with many earthworms generally have more exchangeable mineral nutrients than soils without earthworms. This is because worms play an important role in litter decomposition and incorporation of plant residues into the soil by their burrowing, feeding and casting activities. This topic has been reviewed comprehensively by Edwards and Lofty (1977) and Lee (1985). And several others (Edwards & Lofty 1977 and Lee 1985) stated that total exchangeable cation concentrations increase in the casts, suggesting that the soil organic matter bound ions freed during the passage through the gut. Casts maintain more nutrient materials than the soil (DAsh & Patra 1977, Kale & Krishnamoorthy 1980). Further, Krishnamoorthy & Vajranabhaiah (1986) observed positive correlation between nutrients and earthworm population density. Bhadauria and Ramakrishnan (1991) observed the improvement in the nutrient availability in the surface layer where earthworm inhabit. The several studies at different habitats (e.g. James & Seastdt 1986, Haimi & Huhta 1990, Haimi & Boucelham 1991, Haimi & Einbork 1992 and Curry et al. 1995) confirms the earthworm role in the rate of minealization of nutrients.

A review of the 15 locations investigated show variations with reference to physico-chemical factors, and they strongly relate the earthworm distribution and the study also reveals that probably the forest habitats rich in organic matter and optimal conditions support larger population of earthworms than the wasteland and garden soils. However, a detailed study on seasonal basis is likely to give some more information regarding the earthworm distribution of this region.

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