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ORIGINAL PAPER

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Population dynamics of the earthworm *Amynthas alexandri* (Annelida: Megascolecidae) in a Kumaun Himalayan pasture soil

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Abstract Ecological studies on earthworms were conducted in a Kumaun Himalayan pasture soil. The C:N ratio in the soil declined with increasing depth. A combination of hand-sorting and formalin application was used to sample the earthworms. Three species, *Amynthas alexandri, A. diffringens* (Megascolecidae), and *Eisenia fetida* (Lumbricidae) were found. Of the 13310 individuals collected, 99.9% were *A. alexandri.* The maximum density ($138.8\ m^{-2}$) and biomass ($25.2\ g\ m^{-2}$) were recorded in the wet season. More than 60% of the total earthworm numbers and biomass were recorded at 0–10 cm in depth. The mean yearly ratio of clitellate to aclitellate worms was 1:7.3.

Key words *Amynthas alexandri* · Earthworms · Population dynamics · Vertical distribution · Age structure

Introduction

Earthworms are distributed throughout the world (Stephenson 1930) and are important decomposers of dead plant bodies (Satchell 1967). In India, a number of papers on the ecology of earthworms have been published including those by Dash and Patra (1977), Misra and Dash (1984), and Julka (1986). There are no reports on earthworm ecology in the Kumaun Himalayas.

This paper deals with the faunal composition, population dynamics, and vertical distribution of earthworms as a part of a research programme on nutrient cycling in a Kumaun Himalayan pasture soil.

Materials and methods

Study site

Earthworm were sampled in a 50×30 m site at Government House, Nainital (29°22′ N, 79°28′ E, altitude 2200 m). The dominant plant species are *Trifolium repens, Polypogon fugax, Erigeron karvinskianus, Bromus uniloides, Dicliptera bupleuroides,* and *Cardamine impatiens.*

Climate

Climatic data observed at the nearest meterological station, State Observatory, Nainital, are presented in Fig. 1. The annual rainfall is 2800 mm. On the basis of climatic variations, the year is divisible into three seasons, summer (March–June), rainy (July–October), and winter (November–February).

Soil type

The soil is yellowish and contains 48% sand, 28% silt, 20% gravel, and 4% clay. Soil pH was determined using an electric pH meter. Soil moisture was determined gravimetrically at 105 °C. Organic C was determined using wet oxidation, and P by the wet-ashing method of Jackson (1958). Soil N was determined by Kjel auto VS-KTP Nitrogen Analyzer based on a micro-Kjeldahl technique (Misra 1968). K was determined by flame photometry. Main properties are listed in Table 1.

Earthworm sampling

Earthworm were collected fortnightly by hand-sorting and formalin application, using a quadrat of 50×50 cm, from depths of 0–10 and 10–20 cm. The earthworms were rinsed, dried on blotting paper, weighed, and then preserved in 4% formalin (Rożen 1982).

Table 1 Average chemical characteristics of a pasture soil

Soil characteristics	Soil layer	
	0–10 cm	10–20 cm
Soil pH	6.52±0.06	6.5±0.01
Soil temperature (°C)	11.5±2.6	11.6±2.5
Soil moisture (%)	23.6±0.34	21.0±0.11
K (%)	0.022±0.0007	0.016±0.0001
P (%)	0.0015±0.0001	0.0009±0.00004
Organic C (%)	2.05±0.004	1.96±0.004
N	0.20±0.004	0.20±0.01
C:N ratio	10.25	9.8

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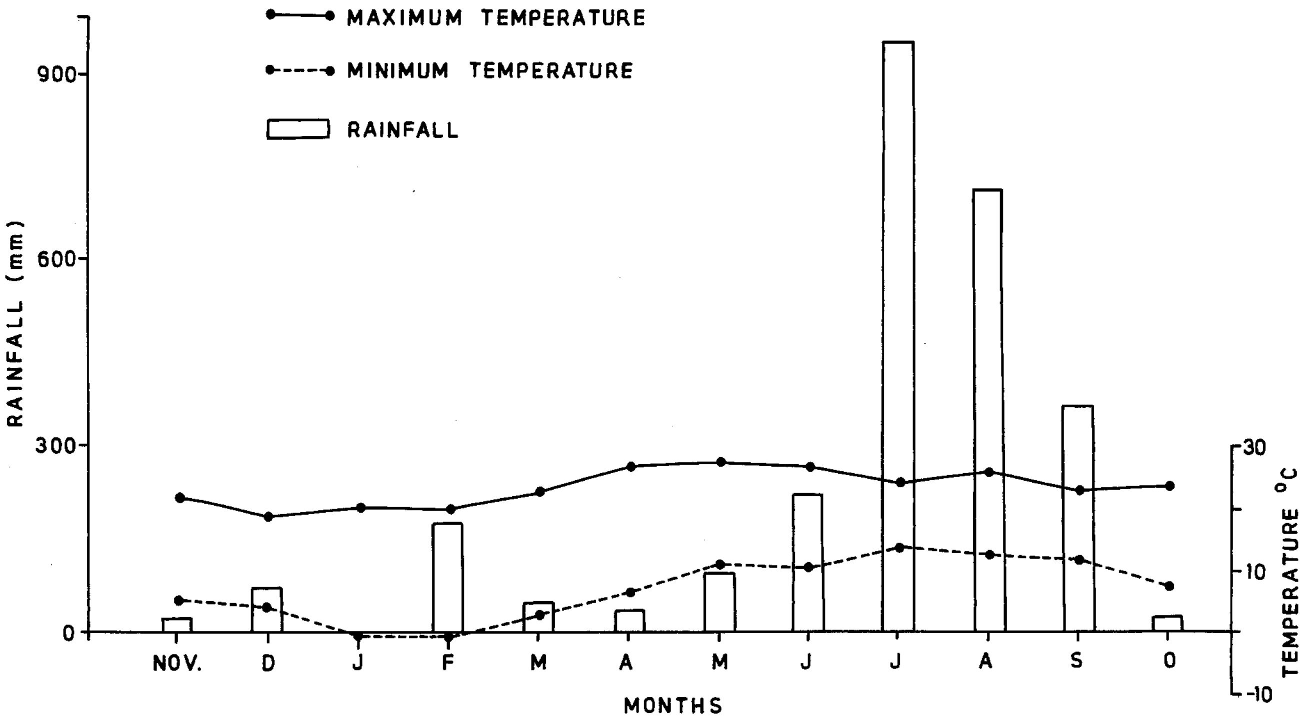

Fig. 1 Temperature and rainfall data for Nainital during 1990–1992

Results

Soil properties

The maximum soil moisture was 36.4 and 33.9% at 0–10 and 10–20 cm respectively, during the rainy period, and the minimum soil moisture was 8.7 and 8.1%, respectively, during the winter season. Soil pH was near neutral in both soil layers.

Organic C and the C:N ratio decreased with increasing depth. The differences in Table 1 are statistically significant according to the standard errors listed. The values are, however, so close in the two soil layers that they are unlikely to have made any difference to soil biological activity.

Species composition

Of 13310 individuals collected in the study site, 13305 were *A. alexandri*, two were *A. diffringens*, and three *Eisenia fetida*.

Total population density and biomass

The abundance and biomass of earthworms are given in Figs. 2 and 3. In 1990–1991, density ranged from 10.0 m^{-2} (7 May) to 138.8 m^{-2} (22 October). Both clitellate and aclitellates were found in maximum numbers in the wet period and minimum numbers in the summer season (Table 2). Aclitellate worms constituted 90.0% of the total earthworm numbers. The mean annual density 61.1 individuals m^{-2}. In 1991–1992, the density ranged from 2.4 m^{-2} (7 June) to 114.8 m^{-2} (22 December). Aclitellates comprised 85.4% of the total earthworm numbers, and the mean annual density was 50.9 individuals m^{-2}. The earthworm biomass ranged from 2.9 g m^{-2} (7 June) to 25.2 g m^{-2} (7 October) in 1990–1991, and from 0.2 g m^{-2} (7 June) to 19.2 g m^{-2} (7 September).

Thus, in both years, the maximum density and biomass were recorded during or towards the end of the wet period and minimum values were obtained during the dry period (summer season).

Vertical distribution of total earthworms

A mean of 64.4% of total earthworms and 63.9% of the total biomass occurred at a depth of 0–10 cm (Table 3). The higher density and biomass at 0–10 cm in comparison with the number of individuals at 10–20 cm indicates that the worms in the upper were relatively large. In both years, the largest numbers earthworms occurred in the wet period (July-October) at 0–10 cm, followed by the winter season (November–February). The lowest numbers were recorded in the summer season (March–June). Data on the vertical distribution of earthworms indicate their habitat preferences.

Age structure

Only two age classes were considered, aclitellates and clitellates. The mean yearly ratio of clitellate to aclitellate

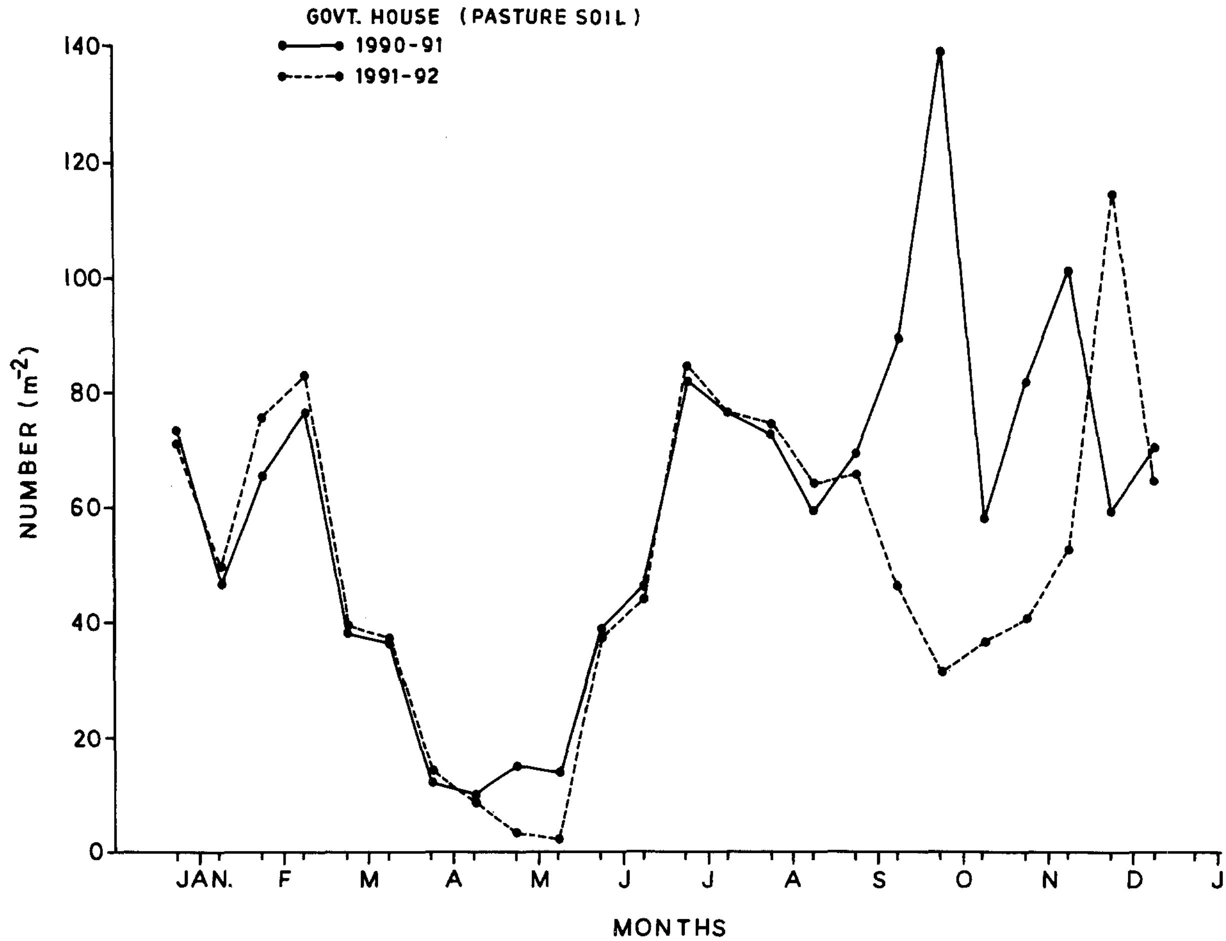

Fig. 2 Seasonal variations in abundance of earthworms during 1990–1992 in a pasture soil at Government (*Govt*) House Nainital

individuals of *A. alexandri* was 1 : 7.3. In both years, the number of clitellates was lower than of aclitellates the whole year round. The age structure of *A. diffringens* and *E. fetida* was not studied because of their very low numbers.

Discussion

Zicsi (1962), Satchell (1967), and Axellson et al. (1971) pointed out that in hand-sorting samples, small earthworms are more easily overlooked than larger ones. According to Raw (1959), the application of formalin expels more earthworms and a larger biomass, especially individuals of *Lumbricus terrestris* in rich soils, than the hand-sorting method. The efficiency of hand-sorting with formalin application as used in the present study has been tested by Raw (1960), Nelson and Satchell (1962), Zajonc (1970), Lavelle (1978), and Terhivuo (1989). This method has the advantage that it can be adapted to extract earthworms at all stages of the life cycle.

Of the three species of earthworms collected in the present investigation, *A. alexandri* and *A. diffringens* are endemic while *Eisenia fetida* is exotic (Julka 1986). The low degree of species richness agrees with the studies of McCredie et al. (1992) but is lower than in many other pasture soils in temperate regions (Lee 1985). However, the number of exotic species recorded in the present study is similar to that reported in other areas (Barley 1959, three species; Van Rhee 1969, four species; Nordstrom and Rundgren 1973, two to eight species; Kalisz and Dotson 1989, one to three species; McCredie et al. 1992, two species). The total dominance of *A. alexandri* might have been mainly due to its feeding habits and, to some extent,

Table 2 Percentage of aclitellate and clitellate worms (total numbers) in different seasons in a pasture soil

Seasons	1990–1991		1991–1992		Mean	
	Aclitellate	Clitellate	Aclitellate	Clitellate	Aclitellate	Clitellate
Summer	15.3	1.4	15.8	2.8	15.6	2.1
Rainy	38.7	5.2	33.2	6.7	36.0	5.9
Winter	36.0	3.4	36.3	5.2	36.1	4.3

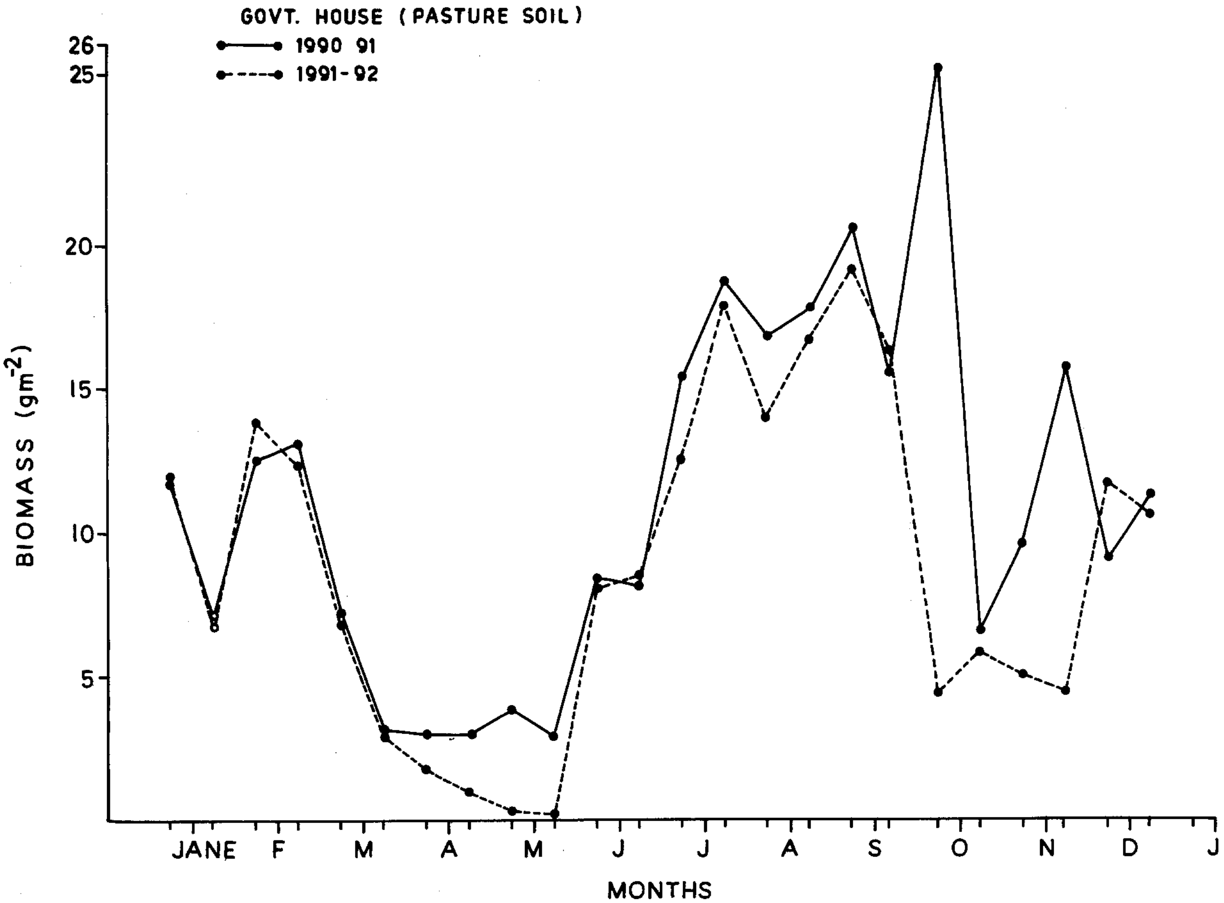

Fig. 3 Seasonal variations in biomass of earthworms during 1990–1992 in a pasture soil at Government (*Govt*) House, Nainital

to its pathenogenetic mode of reproduction (Julka 1986). Because the number of earthworm species was low no attempt was made to analyze their diversity.

The seasonal dynamics over an annual cycle showed that the earthworm populations and biomass were high in the rainy and early winter seasons and low in summer. Dash and Patra (1977) and Kale and Krishnamoorthy (1982) have also recorded maximum numbers of earthworms and the largest biomass in the rainy or late rainy period. We also observed that the number of clitellate worms fell in the summer season and rose again later in the rainy season. The number of aclitellate worms was invariably higher than the number of clitellate worms. No clear seasonal changes in aclitellate worms were apparent at any time, and most important of all, there was no

Table 3 Percentage of earthworms and biomass at 0–10 and 10–20 cm in a pasture soil

Year	0–10 cm		10–20 cm	
	Density (%)	Biomass (%)	Density (%)	Biomass (%)
1990–1991	66.2	63.9	33.8	36.1
1991–1992	62.6	63.9	37.4	36.1
Mean	64.4	63.9	35.6	36.1

winter decrease in numbers. Misra and Dash (1984) and Mohanjit (1986) have reported higher ratios of juveniles to adults for major parts of the year.

In the present study the maximum density and biomass of the earthworms (138.8 m^{-2} and 25.2 g m^{-2}) were within the range of other reported values (Reynoldson 1955; Barley 1959; Khalaf El-Duweini and Ghabbour 1965; Nordstrom and Rundgren 1973; Mackay and Kladivko 1985; McCredie et al. 1992).

The habitat preferences of Lumbricid species have been studied in various localities in Europe and several groupings have been proposed. Julin (1948) divided these earthworms into litter-living and mineral-soil-living species. Depending on the type of habitat they occupy, earthworms can be classified into three ecological groups, epigees or litter dwellers, endogeic or horizontal burrowers, and anecic or deep burrowers (Phillipson et al. 1976). The grouping given by Nordstrom and Rundgren (1973), for example, is (1) weakly burrowing species, surface-living, litter-dwelling (A horizon); (2) intermediary species (B horizon); and (3) strong-burrowing species, deep-burrowing, mineral-soil-living (C horizon).

The habitat preference of *A. alexandri* was clear in the present investigation. This species is a mineral-soil-living and surface-casting species, since 62–66% of the specimens were recorded at 0–10 cm in depth. The proportion of biomass at 0–10 cm was also higher than at 10–20 cm.

Most researchers have found earthworms almost exclusively in the top 50 cm of the soil, and most species have been found in the top 20 cm (Nordstrom and Rundgren 1974; Watanabe 1975; Bouche 1977; Sugi and Tanaka 1978; Piearce 1982; Aina 1984; Tsukamoto 1985; Mato et al. 1988; McCredie et al. 1992). The data obtained in the present work fit this pattern, both for the various species considered and for the earthworm population as a whole. Differences in the vertical distribution of the C : N ratio at 0–10 cm and 10–20 cm paralleled differences in the abundance and biomass of earthworms. The decline in the C : N ratio with increasing depth recorded in the present study is similar to that reported by Tsukamoto (1985).

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