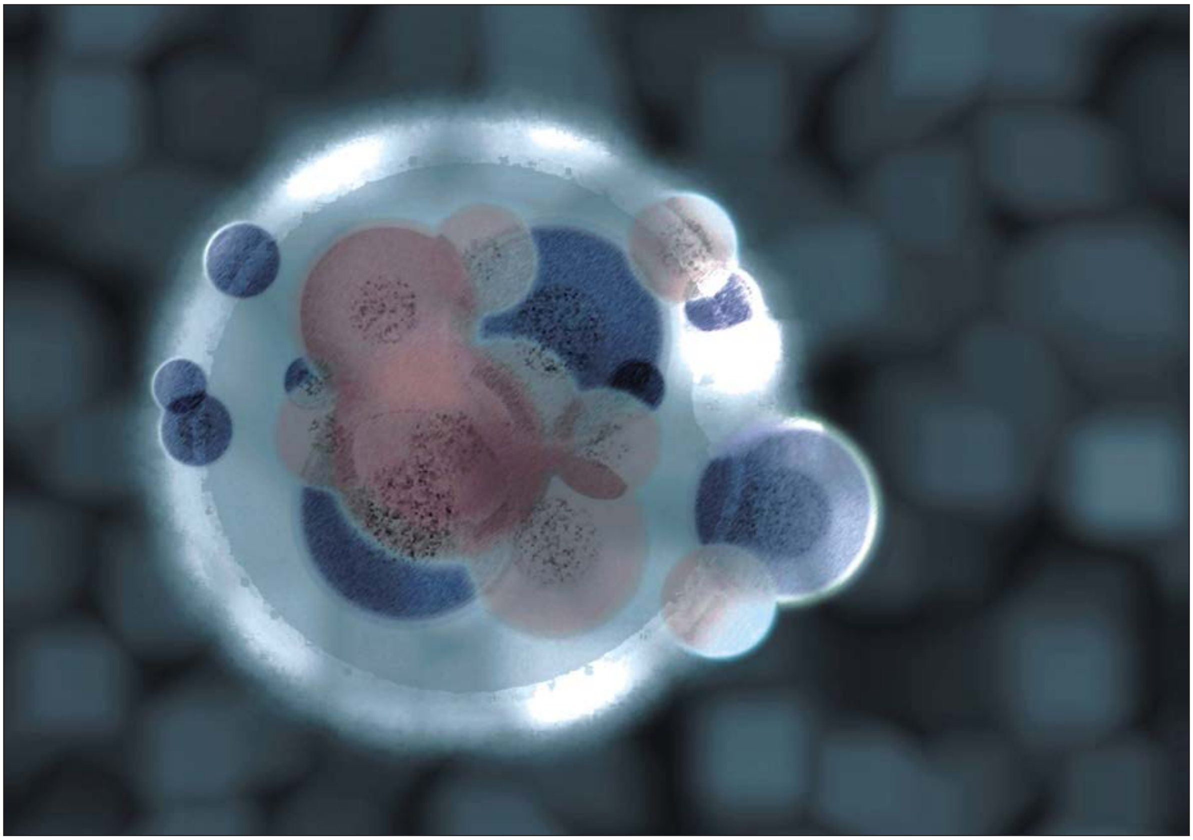

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Abundance, Biomass and Vertical Distribution of Earthworms in Ecosystem Units of Hornbeam Forest

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Abstract: The objectives of this study were to investigate the abundance, biomass and practical distribution of earthworms in ecosystem and tried to identify the factors affecting earthworm populations during different environmental conditions. Density and biomass of earthworms were studied in ecosystem unit's khanikan forests (North of Iran) in July 2006. Eighteen soil profiles (50×50 cm) to the depth of 30 cm were digged and soil samples were taken from organic horizon (litter layer) and mineral layers (0-10, 10-20 and 20-30 cm). Earthworms were collected by hand sorting method, then oven-dried at 60°C and weighed. Comparison number and biomass of earthworms in various layers of soil have showed that most number was in third layer (63.63%) and the least number was in second layer (13.63%). Also, biomass of earthworms in third layer was the most (79.39%) and was the least in second layer (7.57%). Results of this research indicated that correlation between number and biomass of earthworms with C/N, biomass of earthworms with carbon of soil and number of earthworms with theirs biomass were significant. Correlation between number and biomass of earthworms with the other soil properties investigated was no significant.

Key words: Earthworms, biomass, hornbeam, soil properties, Khanikan

INTRODUCTION

Earthworms are the best known and perhaps the most important animals that live in soil. Over 3500 earthworm species have been recognized in worldwide and it is estimated that further surveys will reveal this number to be much larger (Deleporte, 2001; Bohlen, 2002). Earthworms alter soil properties in ways that are beneficial to plant growth by improving soil structure for better aeration, water intake and water transmission and, are known to have various beneficial effects on soil physical properties (Kimmins, 1987; Haynes *et al*., 2003; Rombke *et al*., 2005; Sautter *et al*., 2006).

Earthworms play a major role in soil nutrient dynamics by altering the soil physical, chemical and biological properties. Their casts, burrows and associated middens constitute a very favourable microenvironment for microbial activity (Hale *et al*., 2005; Hale and Host, 2005). They affect nutrient cycling by modifying soil porosity (Ammer *et al*., 2005) and aggregates structure (Sheehan *et al*., 2006), changing the distribution and rates of decomposition of plant litter and altering the composition, biomass and activity of soil microbial communities (Jimens *et al*., 2006).

Where earthworms are abundant, direct fluxes of nutrients through theirs biomass can be considerable, for example, up to 150 kg of nitrogen per h per year have been reported to turn over in earthworm tissue (Neirynck *et al*., 2000; Hendrix and Bohlen, 2002; Hale *et al*., 2005). Earthworm's species can be grouped according to behavioral, morphological or physiological adaptations that enable them to partition available resources in the soil. The three main life history strategies are termed epi, anecic and endogeic (Bohlen, 2002; Haynes *et al*., 2003; Hale *et al*., 2005; Hale and Host, 2005; Muratake, 2005; Amador *et al*., 2006). Earthworms are the most important members of soil detritivors in temperate forests. Soil productivity and plant growth are significantly affected by biological activities of earthworms. Density and biomass of earthworms represent the biological activity and quality of given soils (Rahmani, 1998).

Investigation on the earthworm's population and its relationship with vegetation and soil is a necessity for determining the ecological potential of forest stands. Earthworms population is 1-850 m^2 (0.5-300 g m^{-2}) and biomass of earthworms estimated 30 g m^{-2} (± 20) in temperate forests (Saleh Rastin, 1978).

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The enhancement of their numbers and biomass and consequently their effect on soil fertility are of great interest. In many studies it has been shown that the low earthworm densities found in conifer stands and earthworm productivity can be temporarily enhanced by liming. This often results in a clear change of the humus type after liming (Huhtaq, 1979; Persson, 1988; Ammer and Makaeschin, 1994; Judas, 2002).

It is not clear whether earthworm populations are mainly controlled by the amount of food, its quality, or the chemical properties of their environment (Huhta *et al*., 1986; Scheu and Schaefer, 1998; Aubert *et al*., 2003; Scheu *et al*., 2003; Gonzalez *et al*., 2003) and in which way they are affected by competitive interactions and predation by other invertebrates. The objectives of the present study were to investigation of abundance, biomass and vertical distribution of earthworms in ecosystem units of study area and tried to identify the factors affecting earthworm populations over a wide range of sites with different environmental conditions.

MATERIALS AND METHODS

Study area: Khanikan forests are located in the lowland and midland of Mazandaran province in north of Iran with 2807 ha. (Between 36° 33′ 15″, 36° 37′ 45″ latitude and between 51° 23′ 45″, 51° 27′ 45″ longitude). The maximum elevation is 1400 m and the minimum elevation is 50 m. Minimum temperature is recorded in December (7.5°C) while the highest temperature in June (24.6°C). Mean annual precipitation of the study area were from 237.6 mm to 47.5 mm at the Noushahr city metrological station, which is 10 km far from study area (Anonymous, 2003).

Determine of ecosystem units (Forest types): In order to investigate of vegetation and differentiation of ecosystem units was sampled quadrates in mid-summer 2007. 268.7 ha^{-1} areas of Khanikan forests were selected. Randomized-systematic method was considered with 60 quadrates and 400 m^2 (20 m×20 m) AR (Hedman *et al*., 2000; Grant and Loneragan, 2001; Mesdaghi, 2001) Vegetation data (trees, shrub and herbs) including cover percentage were estimated quantitatively within quadrate and with the use of Two-Way Indicator Species Analysis (TWINSPAN) and vegetation was classified into 5 different groups. These types as follows: *Menta aquatica*, *Oplismenus undulatifolius*, *Carex grioletia*, *Viola odarata* and *Rubus cearius*.

Soil sampling and data collections: After investigate of vegetation and determination of ecosystem units and calculate Sorenson similarity coefficient between groups, the sum 18 profiles (50×50 cm) excavated of determined ecosystem units. Soil samples were selected from organic horizon (litter layer) and mineral layers (0-10, 10-20 and 20-30 cm). Earthworms were removed from the soil by hand- sorting method, washed in water and they were weighed with 0.0001g precision. Species of earthworms were identified (epigeic, anecic and endogeic) by external characteristics using the key of Edwards and Bohlen (1996). Biomass was defined as the weight of the worms after drying for 48 h on filter paper at room temperature (60°C) (Edwards and Bohlen, 1996). Large live plant material (root and shoots) and pebbles in each sample were separated by hand and discarded. The soil samples were air-dried and sieved. Soil pH (saturation paste), bulk density (BD) (clod method), saturation moisture (SP) (weighting method), Electrical Conductivity (EC) (conductivity meter), organic carbon C (Black, 1979), total nitrogen N (Kjeldahl method), Cation Exchangeable Capacity (CEC) (flame photometry method), extractable phosphorous (P) (Olson method), soil texture (hydrometer method), carbon litter (Clit) (Walkey and black method) and nitrogen litter (Nlit) (Kjelteck method) were determined.

Data analysis method: The windows (Ver. 3.0) of PC-ORD (McCune and Mefford, 1999) were used for classification of vegetation. Comparing of means of environmental factors amongst forest types and also study of inter-relationships between these variables was done by one way ANOVA (Analysis of variance) method SAS program version 9.1 was used for ANOVA.

RESULTS AND DISCUSSION

Earthworms have identified in each types. 31.48 and 68.52% of earthworms were endogeic and anecic, respectively. *Carex grioletia* type had the most number of earthworms (45.45%), *Oplismenus undulatifolium* and *Rubus caesius* types had the least number of earthworms (9.09%). Biomass of earthworms in *Menta aquatica* type was the most (41.27%) and in *Rubus caesius* type was the least (1.97%). Comparison number and biomass of earthworms in various layers of soil have showed that most number was in third layer (63.63%) and the least number was in second layer (13.63%). Also, biomass of earthworms in third layer was the most (79.39%) and was the least in second layer (7.57%) (Fig. 1).

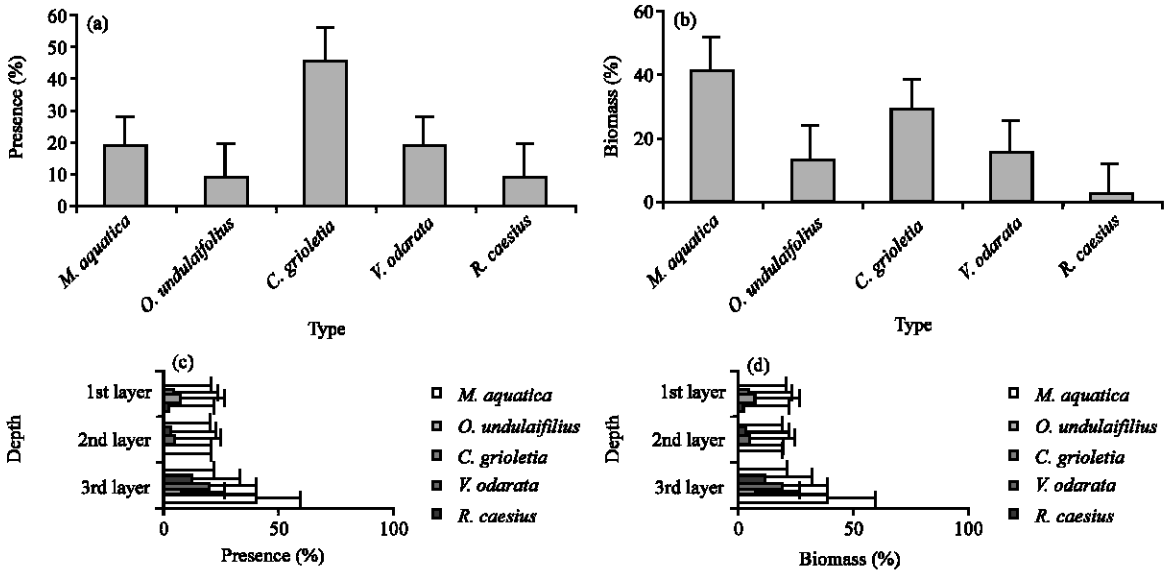

Fig. 1: Percentage abundance and biomass ecological groups of earthworms in different types (a, b) and soil layers (c, d)

Table 1: Mean of soil properties in study area (in different vegetation types)

Vegetation type	Depth (cm)	pH	BD	SP (%)	EC (dS m^{-1})	C (%)	N (%)	C/N	CEC (ppm)
M. aquatica	0-10	6.95	1.26	29.45	0.87	1.71	0.15	10.06	11.40
	10-20	7.18	1.32	64.90	0.82	1.64	0.14	11.52	20.70
	20-30	7.15	1.35	33.57	0.80	0.92	0.08	10.74	10.40
O. undulatifolius	0-10	5.59	0.80	60.74	0.85	3.22	0.24	13.35	26.10
	10-20	5.56	0.94	67.87	0.49	1.69	0.14	12.18	21.50
	20-30	5.52	0.98	60.21	0.45	1.34	0.14	9.89	24.40
C. grioletia	0-10	5.05	0.90	59.34	0.71	3.95	0.35	11.44	22.18
	10-20	5.06	0.90	53.12	0.64	2.94	0.22	12.95	21.60
	20-30	5.02	0.89	72.95	0.41	2.41	0.20	11.04	22.80
V. odarata	0-10	5.09	0.83	65.19	0.65	4.34	0.34	12.57	28.40
	10-20	5.03	0.85	58.76	0.48	2.99	0.23	12.80	28.64
	20-30	5.12	1.05	76.21	0.45	2.11	0.17	11.41	28.64
R. cearius	0-10	5.58	0.45	67.07	0.52	3.65	0.29	12.56	15.60
	10-20	5.25	1.07	63.45	0.49	2.88	0.21	13.75	17.20
	20-30	5.01	1.02	69.20	0.29	1.31	0.10	13.08	20.20

Vegetation type	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Lime (%)	P (ppm)	Clit (%)	Nlit (%)	C/N
M. aquatica	0-10	79.00	8.50	12.50	10.25	3.51	7.08	2.17	3.26
	10-20	86.00	11.00	3.00	20.75	2.73			
	20-30	73.25	22.25	4.50	7.75	2.02			
O. undulatifolius	0-10	68.87	16.31	14.81	5.00	20.92	6.31	1.46	4.32
	10-20	68.75	15.43	15.81	3.37	13.18			
	20-30	70.50	12.93	16.56	7.00	17.63			
C. grioletia	0-10	58.60	27.60	13.80	4.20	14.62	6.62	1.41	4.69
	10-20	49.80	29.80	20.40	4.60	10.51			
	20-30	51.40	26.40	24.20	3.20	10.00			
V. odarata	0-10	65.20	20.95	13.85	3.60	15.65	6.62	1.42	4.66
	10-20	61.20	18.90	17.90	5.20	13.62			
	20-30	60.80	15.70	23.50	6.30	13.47			
R. cearius	0-10	59.00	30.00	11.00	8.00	6.71	6.79	1.40	4.85
	10-20	73.50	18.50	12.50	8.00	2.06			
	20-30	71.00	12.87	16.12	4.50	4.86			

BD: Bulk density , SP: Saturation moisture, Clit: Carbon of litter, Nlit: Nitrogen of litter

Results of this study indicated that correlation between number and biomass of earthworms with soil properties (Table 1) such as C/N, biomass of earthworms with Carbon of soil and number of earthworms with theirs biomass were significant. Correlation between number and biomass of earthworms with the other soil properties investigated was no significant (Table 2).

Table 2: ANOVA for number and biomass of earthworms in relation to soil properties

	Mean square		F-value		CV		R^2		p>F	
Variable factors	No. of earthworms	Biomass of earthworms	No. of earthworms	Biomass of earthworms	No. of earthworms	Biomass of earthworms	No. of earthworms	Biomass of earthworms	No. of earthworms	Biomass of earthworms
pH	±0.040.0002	±0.020.01	0.00	0.54	38.11	20.13	0.00	0.01	0.96	0.46
CEC	±0.040.15	±0.020.03	1.36	1.69	37.62	19.91	0.02	0.03	0.24	0.19
BD	±0.040.03	±0.020.03	0.29	1.58	38.01	19.93	0.005	0.02	0.59	0.21
P	±0.040.01	±0.020.01	0.13	0.58	38.07	20.12	0.002	0.01	0.71	0.44
Lime	±0.040.008	±0.020.002	0.07	0.10	38.09	20.21	0.001	0.001	0.78	0.75
SP	±0.040.09	±0.020.03	0.84	1.46	37.81	19.95	0.01	0.02	0.36	0.23
Sand	±0.040.15	±0.020.002	1.36	0.08	37.62	20.22	0.02	0.001	0.24	0.77
EC	±0.040.12	±0.020.01	1.10	0.79	37.72	20.08	0.02	0.01	0.29	0.37
Silt	±0.040.05	±0.020.003	0.51	0.12	37.93	20.21	0.009	0.002	0.47	0.72
C/N	±0.040.71	±0.010.11	7.13	5.45	35.74	19.25	0.12	0.09	0.01	0.02
C	±0.040.38	±0.010.09	3.59	4.40	36.86	19.43	0.06	0.07	0.06	0.04
Clay	±0.040.09	±0.02 0.0004	0.89	0.02	37.79	20.23	0.01	0.0003	0.35	0.89
BE	±0.024.37	-	149.76	-	19.35	-	0.74	-	0.0001	-
N	±0.040.12	±0.020.04	1.11	1.99	37.71	19.85	0.02	0.03	0.29	0.16
Clitt	±0.20.05	±0.080.002	0.02	0.01	129.30	189.70	0.001	0.0004	0.87	0.93
Nlitt	±0.20.05	±0.08 0.08	0.02	0.18	129.30	188.60	0.01	0.01	0.88	0.67

Forest exploitation has increased due to increase of human populations and application woods in many industries. Plain forests north of Iran have destroyed due to entry of heavy logging machines to purpose much logging. This is important that presence and absence of earthworms depended by organic matter and litters. With forest destroyed, organic matter and litters have lost. Result of this research has showed (Fig. 1) that scatter of earthworms is not homogenous and various species of earthworms exists in different depths (Wood, 1995; Holscher *et al*., 1999).

The most worldwide soils, earthworms have seasonal migration in vertical direction that it is due to unfavourable conditions in higher layers of soil. Temperature and moisture of soil are the effective factors (Wood, 1995; Edwards *et al*., 1973; Saleh, 1978; Iman Nejad and Rahmani, 2005). More density of earthworms in deeper soils (20-30 cm) in this research is due to this subject (Fig. 1).

Favorable conditions exist in spring and autumn seasons for growth of earthworms, thus, increases their populations. In winter and summer season's unfavourable conditions such as cold of winter and height of summer decreases their population (Rahmani, 1998). Earthworms in summer and winter seasons will migrate to more depths of soils and abides in there (Haghparast, 1993; Rahmani, 1998; Six *et al*., 2004).

Correlation between number and biomass of earthworms were investigated with the some soil properties (Table 1). Results have showed significant correlation between number and biomass of earthworms with C/N of soil ($p< 0.05$), Biomass of earthworms with carbon of soil ($p<0.05$) and between number and biomass of earthworms ($p<0.001$) (Table 2). Number and biomass of earthworms are fewer in soils with higher C/N. This result confirms those obtained in previous studies. Wood (1995) had resulted the mineral matters are necessity for growth of earthworms and biomass of earthworms are much is soils with fewer C/N. Neirynck *et al.* (2000) researches had showed that the fewer C/N of soils in beneath of *Pseudo platanus* crown cover is suitable for presence of earthworms. Rahmani and Saleh Rastin (2000) resulted the number of earthworms is depended to C/N of soil and higher C/N decreases earthworm populations.

In soils with strong biological activities, content of C/N is low (<10) (Habibi Kaseb, 1992) but in this research C/N content was between 9.8-13.7 (Table 2), thus, pay attention to this subject, biological activities of study area soils were weak. Also, exists significant negative correlation between biomass of earthworms with carbon of soil. Correlation between numbers of earthworms with carbon of soil was close to significant ($p>f = 0.0636$). Acidity of soils study area was low in all types and is similar in various depths. Totally, earthworms are sensitive to pH and in acidophilus forest sites with similar soil pH and humus form (moder or mor) species richness and abundance are low (Wood and James, 1993; Edwards and Bohlen, 1996; Neirynck *et al*., 2000; Six *et al*., 2004).

Between number of earthworms and theirs biomass exists significant positive correlation ($p<0.001$). This result is similar to results of research of Haynes *et al.* (2003) that more presence of earthworms in soil resulted more biomass. Epigeic ecological groups, prefers conditions with high nutrition and litters with low C/N. Endogeic and anecic ecological groups are tolerance to unfavourable conditions and enable tolerates soil dry because of they are enable to migrate higher depths of soil (Hale and Host, 2005). This subject is visible in this research (Fig. 1). Correlation between number and biomass of earthworms with the other soil properties investigated was no significant.

Earthworms are known to have a positive influence on the soil fabric and on the decomposition and mineralization of litter by breaking down organic matter and producing large amounts of fasces, thereby mixing litter with the mineral soil. Therefore, they play an important part in changes from one humus from to another according to forest succession patterns. Consequently, the are also expected to be good bio-indicators for forest site quality and are thus useful when planning forest production improvement. Earthworm's populations are as indicator that in exploited regions is destruction indicator and reclamation plans is nature return indicator.

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