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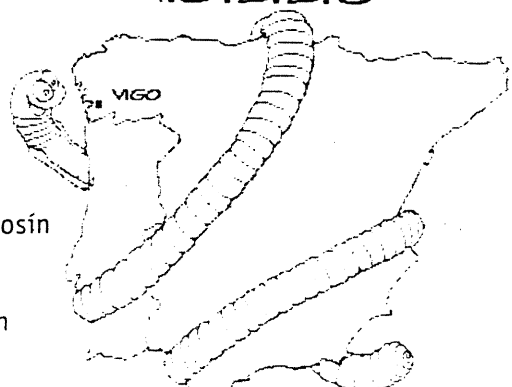

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Effect of soil compaction and organic matter removal on two earthworm populations and some soil properties in a hardwood forest

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Summary. Earthworms can alter the physical, chemical, and biological properties of a forest ecosystem. Any physical manipulation to the soil ecosystem may, in turn, affect the activities and ecology of earthworms. The effects of organic matter removal (logs and forest floor) and soil compaction on earthworm activities were measured in a central hardwood region (oak-hickory) forest in the Missouri Ozarks. Soils in this region are characterized by a cherty residuum that is primarily of the Clarksville series (Loamy-skeletal, mixed, mesic Typic Paleudults). Earthworms were collected from a 15 cm depth each spring and fall for 2 years by the handsorting method and estimated on a per meter square basis. Two earthworm species, *Diplocardia ornata* and *Diplocardia smithii*, were the most dominant native species found in the site. Organic matter removal decreased the average individual biomass of both species. However, these species responded differently to soil compaction. Soil compaction affected *D. ornata* adversely and *D. smithii* favorably. This suggests that the degree of soil compaction was not restrictive to *D. smithii* (2-mm dia) but it was to *D. ornata* (5 mm dia). Moreover, the apparent better soil environmental conditions resulting from the remaining organic matter in compacted soil enhanced *D. smithii* population and growth. Sampling position affected *D. ornata* but not *D. smithii*. Other factors influencing the ecology and activity of these two species will require further study.

Key words: Earthworm, organic matter, compaction, hardwood

Introduction

Any physical manipulation to the soil ecosystem may affect the distribution, activities and ecological environment of earthworms. In forest soils where logging and harvesting may be common commercial practices, the long-term effect of these practices on soil productivity and forest health are of great concern to researchers and the national forest service. Management practices that ensure long-term sustainability of forests are a national priority (Ponder &

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Mikkelson 1995) set forth by the forest service through a network of coordinated long-term experiments established across the United States. In Missouri, the experiments focus on the long-term impacts of soil compaction and organic matter removal (merchantable logs, boles, and forest floor removed) on various soil properties.

Soil compaction from the use of heavy logging equipment in forest ecosystems or from tractors in agricultural systems have been studied for a number of years (Youngberg 1959; Dyrness 1965; Lindermann et al. 1982). The effects of compacted soil on plant growth and root development is also well documented in the literature (Froehlich 1979; Lindermann et al. 1982). However, very few studies are on the impact of soil compaction on native earthworm species and microbial activity in forest soils. Furthermore, any manipulation like harvesting and removal of the organic matter (logs, boles, or forest litter) may have an effect on the microbial and earthworm activity. The objective of this study was to evaluate the effects of soil compaction and organic matter on two native earthworm species, microbial activity, and soil properties in an oak-hickory forest in southeastern Missouri.

Materials and Methods

The study site was located on an area of the Missouri Department of Conservation Carr Creek State Forest in Shannon County near Ellington, Missouri. The site is the location of a USDA Forest Service Long-Term Soil Productivity Study (Powers et al. 1989). The soil at the site was a loamy-skeletal, mixed, mesic Typic Paleduits. The mean annual precipitation at this site is 112 cm and the mean annual temperature is 13.3 °C. The study is located on the upper northeastern-facing side slopes (20–28 %) of two parallel ridges. The oak-hickory timber is the major forest type in the Central hardwood region and occurs over a variety of soils, relief, and stand conditions.

The experiment was a three factor randomized complete block design (RCBD) with two levels and three replications. Experimental factors were organic matter removal (OMo and OM_2) with OMo representing plots with only merchantable logs removed and OM_2 representing all above ground biomass (including logs) plus the forest floor. The forest floor was removed initially by raking the material from the plots. Soil compaction included no compaction, Co and severe compaction, C_2 with a bulk density to 1.8 g cm^{-3}. Soils have been compacted to a depth of 30 cm by removing logs with a skidder and using a roller to severely compact the soils. Sampling position was also a factor which included samples from the top or the bottom of the plot.

Earthworms were collected from a 15 cm depth (30.5 × 30.5 cm) each spring and fall for two years. Earthworms were anesthetized with 70 % ethanol and preserved in 10 % formalin and later identified using the somatic key of James (1990). Ash-free biomass (AFB) was determined by the method of Parmelee et al. (1990).

Soil samples were taken from a 0–15 cm depth and kept cool until subsequent laboratory analyses. For each soil sample, soil moisture (MC, dried at 105 °C for 24 hours), soil inorganic N, (SIN, 0.5 M k_2SO_4 extract) and soil microbial C and N (SMBC, Horwath & Paul 1994 and SMBN, Brooks et al. 1985, respectively) were determined.

Data were analyzed by ANOVA (SAS 1989) using split plot with treatments as the mainplot and sampling time as the subplot to account for repeated sampling of the same experimental plots. Duncan Multiple Range Test (DMRT) and Least Significant Difference (LSD) mean separation tests were used where significant differences occurred. Pearson correlation was used as a simple correlation analysis.

Results

Diplocardia ornata (5-mm, diameter) and *Diplocardia smithii* (2-mm, diameter) were the dominant native species found in this oak-hickory forest in Missouri (USA). Total populations of earthworms collected from the site increased with time. Both *D. smithii* and *D. ornata* were responsible for this increase (Fig. 1). The buildup in *D. smithii* population was more rapid than *D. ornata*. In 1997, *D. smithii* population exceeded that of *D. ornata*, 16 % more in spring and 4 % more in the fall (Fig. 2). *D. smithii* had an annual variation while *D. ornata* had a seasonal variation (Fig. 2) due to higher number of juvenile species.

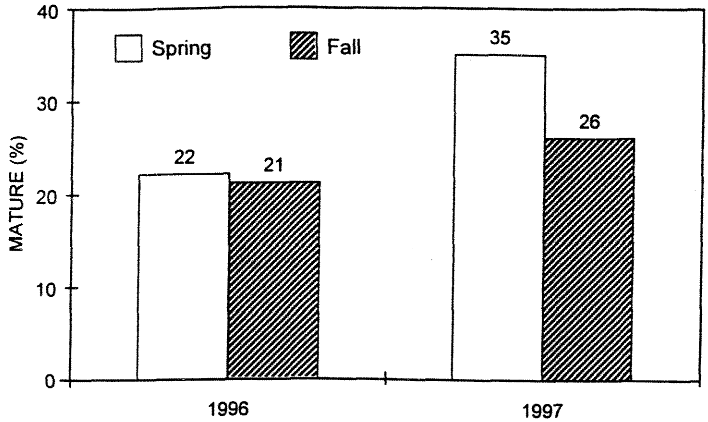

Fig. 1. Mature earthworm populations distribution based on total populations of both species including juveniles

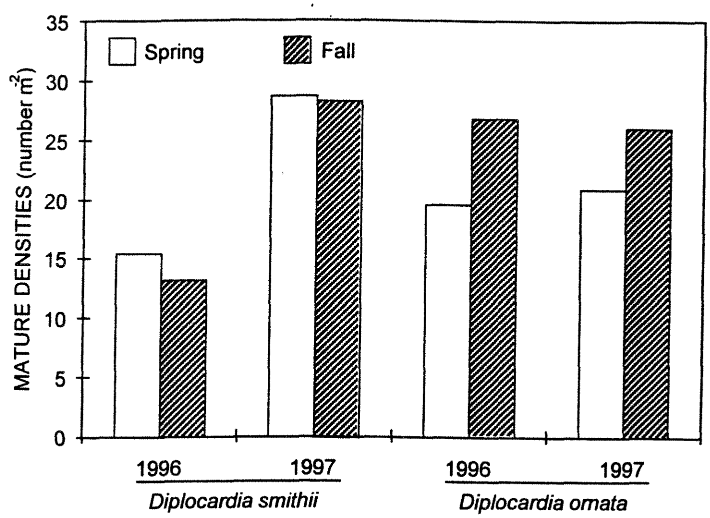

Fig. 2. Mature earthworm densities in spring and fall of 1996–1997

Organic matter removal significantly affected *D. smithii* and *D. ornata* averaged AFB and all the soil properties measured (Table 1). There was a positive correlation between *D. smithii* averaged AFB and SIN and a positive correlation between *D. ornata* averaged AFB and SMBC (data not shown). *Diplocardia smithii* individual AFB, *D. ornata* individual AFB, MC, SIN, SMBC, and SMBN decreased with organic matter removal (Table 1). *D. ornata* population and AFB decreased with soil compaction while *D. smithii* population and AFB increased with soil compaction.

Soil compaction affected *D. smithii* and *D. ornata* quite differently (Table 1). Soil compaction had an average positive effect on *D. smithii* but a negative effect on *D. ornata*. Significantly greater *D. ornata* population and AFB were found in noncompacted soil than in compacted soil. Significant positive effect of soil compaction on *D. smithii* was recorded in spring and fall 1997.

Table 1. Analysis of variance summary table for earthworm variables and soil properties, USDA-FS, 1996–1997 ($P^{††}$)

Source of Variation	df	Total†	Juvenile	*D. smithii*			*D. ornata*			Soil properties‡			
		population	population	population	AFB§	AFB¶	population	AFB§	AFB¶	MC	SIN	SMBC	SMBN
		number m^{-2}	*number* m^{-2}	*number* m^{-2}	$g\ m^{-2}$	$g\ pc^{-1}$	*number* m^{-2}	$g\ m^{-2}$	$g\ pc^{-1}$	%	$mg\ kg^{-1}$	$mg\ kg^{-1}$	$mg\ kg^{-1}$
Replication	2	0.2451	0.4147	0.1613	0.1333	0.1665	0.2749	0.3416	0.6306	0.2278	0.8702	0.9609	0.6138
OM removal (OMR)	1	0.5193	0.4839	0.6727	0.6681	0.0001	0.5271	0.7342	0.0047	0.0038	0.0001	0.0006	0.0004
Soil Compaction (Compaction)	1	0.1522	0.1024	0.1672	0.0690	0.1006	0.0251	0.0703	0.6471	0.1729	0.6563	0.1198	0.1624
Position	1	0.0633	0.1281	0.1353	0.2237	0.1327	0.0275	0.0274	0.0135	0.4616	0.5833	0.6890	0.7365
OMR*Compaction	1	0.9465	0.8058	0.4697	0.2642	0.7268	0.5372	0.7099	0.0466	0.0008	0.0892	0.2159	0.0042
OMR*Position	1	0.6951	0.6134	0.8119	0.6180	0.9913	0.7205	0.7856	0.5199	0.5605	0.9654	0.9993	0.9515
OMR*Compaction*Position	1	0.8654	0.7892	0.7182	0.7911	0.1158	0.7703	0.6980	0.7021	0.3929	0.2184	0.4960	0.8605
Error A	14												
Time	3	0.0081	0.0863	0.0001	0.0002	0.0001	0.0304	0.0522	0.2156	0.2362	0.0001	0.0021	0.0001
OMR*Time	3	0.9473	0.7526	0.6764	0.5825	0.0075	0.7425	0.7164	0.2903	0.2958	0.0210	0.9600	0.9254
Compaction*Time	3	0.1414	0.0851	0.1744	0.1805	0.0459	0.3561	0.1684	0.9178	0.4095	0.3808	0.4528	0.7679
Position*Time	3	0.6328	0.7042	0.1682	0.3783	0.1678	0.5258	0.7369	0.6420	0.7202	0.4914	0.4705	0.9311
OMR*Compaction*Time	3	0.6445	0.8258	0.6121	0.8645	0.0899	0.9692	0.9100	0.0621	0.9892	0.2318	0.1482	0.9517
OMR*Position*Time	3	0.7227	0.9133	0.7829	0.8958	0.5084	0.6564	0.7900	0.8067	0.6999	0.5958	0.7482	0.8771
Compaction*Position*Time	3	0.4013	0.9384	0.0586	0.1308	0.5454	0.0944	0.1442	0.0543	0.3508	0.2429	0.6568	0.5922
OMR*Compaction*Position*Time	3	0.7121	0.6984	0.9730	0.9330	0.7854	0.2532	0.4461	0.0634	0.9843	0.3298	0.6575	0.8750
Time*Replication	6	0.0644	0.0810	0.7973	0.6657	0.1060	0.0717	0.0843	0.8369	0.0001	0.4748	0.6591	0.4218
Error B	42												

† Total earthworm populations included mature and juvenile species.
‡ MC – moisture content; SIN – soil inorganic N; SMBC and SMBN – soil microbial biomass C and N.
§ Total earthworm ash-free biomass in a square meter area.
¶ Individual earthworm averaged ash-free biomass.
†† Significance probability; $P < 0.05$ is significant and $P > 0.05$ is not significant

Sampling position significantly influenced all *D. ornata* variables (Table 2). Significantly more *D. ornata* were found in the bottom of the plot compared to the top of the plot. Sampling position did not significantly affect any of the soil properties, soil moisture, soil inorganic N and soil microbial biomass C and N. Slightly greater soil moisture and soil microbial biomass C were seen at the bottom of the plots.

Table 2. Effect of sampling position on earthworm variables and soil properties, USDA- FS, 1996–1997†

Sampling position	*Diplocardia smithii*			*Diplocardia ornata*			Soil properties‡			
	population	AFB§	AFB¶	population	AFB§	AFB¶	MC	SIN	SMBC	SMBN
	number m^{-2}	*g* m^{-2}	*g* pc^{-1}	*number* m^{-2}	*g* m^{-2}	*g* pc^{-1}	%	*mg* kg^{-1}	*mg* kg^{-1}	*mg* kg^{-1}
Top	3.2 a	0.327 a	0.083 a	3.0 b	0.793 b	0.278 b	27.04 a	27.3 a	626 a	107.6 a
Bottom	5.7 a	0.489 a	0.078 a	6.9 a	1.972 a	0.296 a	27.65 a	22.4 a	636 a	109.5 a

† Mean separation by Duncan at $P \leq 0.05$.
‡ MC – moisture content; SIN – soil inorganic N; SMBC and SMBN – soil microbial biomass C and N.
§ Total earthworm ash-free biomass in a square meter area.
¶ Individual earthworm averaged ash-free biomass

Moisture content had a highly significant positive correlation with SIN, SMBC, and SMBN (data not shown). Soil inorganic N had a positive correlation with both SMBC and SMBN. Additionally, SMBC and SMBN had a highly significant correlation.

Discussion

Organic matter (OMo) which remained on the plots increased each earthworm species growth and population and also increased soil moisture, soil inorganic N and soil microbial biomass C and N. Soil compaction (C_2) affected each earthworm species differently. *Diplocardia smithii* population growth were not inhibited by severe soil compaction compared to *D. ornata*. Significantly greater growth and population of *D. ornata* was observed in noncompacted plots. Our findings on the negative effects of soil compaction on earthworms were consistent with other researchers (Bostrom 1986; Pilz 1992). Pilz (1992) also suggested that earthworms might have a loosening effect on compacted soil.

Seasonal effects (spring vs. fall) are important considerations when describing the distribution of *D. ornata* in this ecosystem. Juvenile populations tended to dominate regardless of species and time of year suggesting that both earthworms reproduce throughout the year. This is consistent with the findings of James (1990) for *D. smithii*.

Sampling position (top vs. bottom of the plot) had a significant effect on *D. ornata*. This may be due to a slight increase in soil moisture and food source at the bottom of the plot. However, these factors are confounding and further study is required.

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References

Bostrom, U. (1986) The effect of soil compaction on earthworms (Lumbricidae) in a heavy clay soil. Swedish Journal of Agricultural Research 16, 137–141.

Brooks, P. C., Landman, A., Pruden, G., Jenkinson, D. S (1985) Chloroform fumigation and the release of soil nitrogen: a direct extraction method to measure microbial biomass nitrogen in soil. Soil Biology and Biochemistry 17, 837–842.

Dyrness, C. T. (1965) Soil surface condition following tractor and high-lead logging in the Oregon Cascades. Journal of Forestry 63, 272–275.

Froehlich, H. A. (1979) Soil compaction from logging equipment: effects on growth of young *Ponderosa* pine. Journal of Soil and Water Conservation 34, 276–278.

Horwath, W. R., Paul, E. A. (1994) Microbial biomass. In: Weaver, R.W., Angle, J. S., Bottomley (eds). Methods of Soil Analysis: Microbiological and Biochemical Properties. pp. 753–771. SSSA Book Series 5, Madison.

James, S. W. (1990) Oligochaeta: Megascolecidae and other earthworms from southern and midwestern North America. In: Dindal, D.L. (ed) Soil Biology Guide. John Wiley and Sons, New York. pp. 379-386.

Lindermann, W. C., Ham, G. E., Randall, G. W. (1982) Soil compaction effects on soybean nodulation, N_2 (C_2H_4) fixation and seed yield. Agronomy Journal 74, 307–311.

Parmelee, R. W., Beare, M. H., Cheng, W., Hendrix, P. F., Rider, S. J., Crossley, Jr., D. A., Coleman, D. C. (1990) Earthworm and enchytraeids in conventional and no-tillage agroecosystems: a biocide approach to assess their role in organic breakdown. Biology and Fertility of Soils 10, 1–10.

Pilz, V. (1992) Effect of soil compaction on earthworms (Lumbricidae) in apple orchard soil. Soil Biology and Biochemistry 24, 1573-1575.

Ponder Jr., F., Mikkelson, N. M. (1995) Characteristics of a long-term forest soil productivity research site in Missouri. In: Proceedings of the 10th Central Hardwoods Forest Conference. pp. Morgantown.

Powers, R. F., Albans, D. H., Raurk, G. A., Goudey, C. B., Ragus, J. F., Russell, W. E. (1989) Study plan for evaluating timber management impacts on long-term site productivity: A research and National Forest System cooperative study. Jefferson City, MO. USDA For. Ser. North Central Forest Exp. Station. 33 pp.

SAS Institute, Inc. (1989) SAS/STAT User's Guide, Ver. 6, Vols. 1 and 2, 4th Ed. Cary.

Youngberg, C. T. (1959) The influence of soil conditions, following tractor logging, on the growth of planted Douglas-fir seedlings. Soil Science Society of America Proceedings 23, 76–78.