HABITAT PREFERENCES AND EFFECT OF ENVIRONMENTAL FACTORS ON THE SEASONAL ACTIVITY OF *LITHOBIUS NIGRIPALPIS* L. KOCH, 1867 (CHILOPODA: LITHOBIOMORPHA: LITHOBIIDAE)

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ABSTRACT: *The activity of animals is defined mostly by internal genetic mechanisms, but physical factors, such as temperature, soil Ph, light duration, and humidity, play a role in the regulation of this biological process. For centipedes, for example, humidity is one of the key environmental factors that determines their distribution and activity. However, abiotic and biotic factors such as soil pH, temperature, vegetation type, and human disturbance remain relatively understudied and little is known on their importance for the centipede activeness. Here we present a study on the habitat preferences and seasonal activity of Lithobius nigripalpis L. Koch, 1867, a species that is widely distributed in the Balkan Peninsula, adjacent parts of Romania, and Anatolia. The study was carried out from May 2007 to May 2009 in the city of Shumen, NE Bulgaria, and its surroundings. Pitfall trapping had been used to determine the seasonal activity and habitat preferences of the species in a range of ecosystems subjected to different degrees of human pressure. Using the software packages SPSS 9.0 and Stat Plus 3.5.3.a number of statistical analyses were employed to test which environmental factors are relevant to the activity and distribution of the species. Our study revealed that in the studied region L. nigripalpis is euryoecious species, which occurs in all habitat types. However, it demonstrates clear preference for undisturbed open habitats, in particular xerothermic shrubby grasslands of the phytocoenose Festuco-Brometea. The current levels of urbanization of the city do not seem to have any significant effect on the distribution and activity of the species concerned. L. nigripalpis exhibits highest activity during summer season (June to September), with peaks in July and August. The environmental factors that have highest significance for its seasonal activity are air and soil temperature, and soil humidity.*

KEYWORDS: Lithobius Nigripalpis, Habitat Preferences, Correlation, Regression Model, Analysis Of Variance.

INTRODUCTION

Despite the fact that centipedes are quite common in both anthropogenically influenced habitats (city parks, cultivated areas, and buildings), as well as in grassy or open natural habitats and in caves, they are typical wood dwellers [12, 16, 21]. Their biomass per unit area in the forests is usually bigger than that of any other main class of invertebrate predators [8, 13] which makes Chilopoda one of the main components of the forest predator fauna. The specialised literature on the topic provides scarce data on the density of the populations, the variety of species, the structure of Chilopoda communities in the various habitats, as well as on their role in the study of biocoenosis [23]. The seasonal activity of separate species of

Chilopoda is the subject of a restricted number of studies which sometimes provide quite contradictory data. This is probably due to the use of different methodological approaches in the collection of material as well as in the analysis of the results [14]. Being predators, Chilopoda do not have such a prominent trophic dependence on the specific type of vegetation community as the other big class of myriapods (Diplopoda). The latter, as typical detritivores and saprophagus, exhibit greater trophic dependence on the composition of vegetation formations and the nutrition base they offer [7, 18, 19]. The majority of the studies on the fauna feature only a description of the habitats where one or another species has been found and very rarely include data on the ecology and the habitat preferences of the species. The presence of a specific species of Chilopoda in a particular habitat is determined mostly by the abundance and accessibility of specific micro-habitats as well as by the complex of soil and climate conditions which it offers [23].

Humidity is undoubtedly the most significant factor of the environment that influences Chilopoda's distribution and activity [4, 12, 14, 23]. In some deciduous forests in the region of Chicago the average density of centipedes is with very low values in January, rises in the period March-May, reaches its peak in August, and has a second peak in numbers in December. The increase in the number of species is accompanied by an increase in precipitation, temperature and the relative air humidity [2].

The seasonal activity of Chilopoda is determined to a bigger degree by the specific biological and ontogenetic peculiarities of the separate species and of their reproductive strategies. During some research on the forest macroarthropoda fauna in North-East England [22] there have been established statistically significant differences in the density of the populations of *Lithobius crassipes* and *Lithobius forficatus* – very high in summer and fall and low in spring and winter. However, these fluctuations in the density of the populations do not correspond to the dynamics in the values of temperature and humidity, but follow the generative strategies of the specific species. *L. crassipes* exhibits bi-modal seasonal activity which coincides with the peaks in the reproductive periods of the species (in June and September), while *L. forficatus* which breads once a year – in September, has the highest activity in that month.

The research on the spatial distribution of myriapod fauna in Skopje and its vicinities (Macedonia) analysed in the context of urban-rural gradient offer some general data on the seasonal activity of Lithobiidae [11]. In natural habitats Lithobiidae exhibit bi-modal surface activity with a peak in the number of individuals in February and a second one, which is smaller, in July, and the oscillations in the activity in the urban and suburban habitats are insignificant. The research just mentioned, as well as many other studies, makes a distinction only between separate orders and families [22]. The presence of scarce data on the activity of specific species, *Lithobius nigripalpis* included, limits our ability for comparison and discussion on the results acquired by us.

MATERIAL AND METHODS

Study Area

The material has been collected from 8 sites, distinguished by their location, composition of plant formations and level of anthropogenic pressure. Two of them are located in a heavily urbanized area which is subject to considerable human pressure: **UI** – City park of Shumen and **UII** – University of Shumen park.The third site **SU** – Kyoshkovete Park, is located in a transitional zone between urban and rural areas. Collecting sites 4-8 are situated in rural habitats located in the Natural Park Shumen Plateau: **RI** – beech forest at Bukaka reserve, **RII** – mixed deciduous-coniferous forest, **RIII** – hornbeam forest, **RIV** – pine forest and **RV** – Open meadow (Fig. 1).

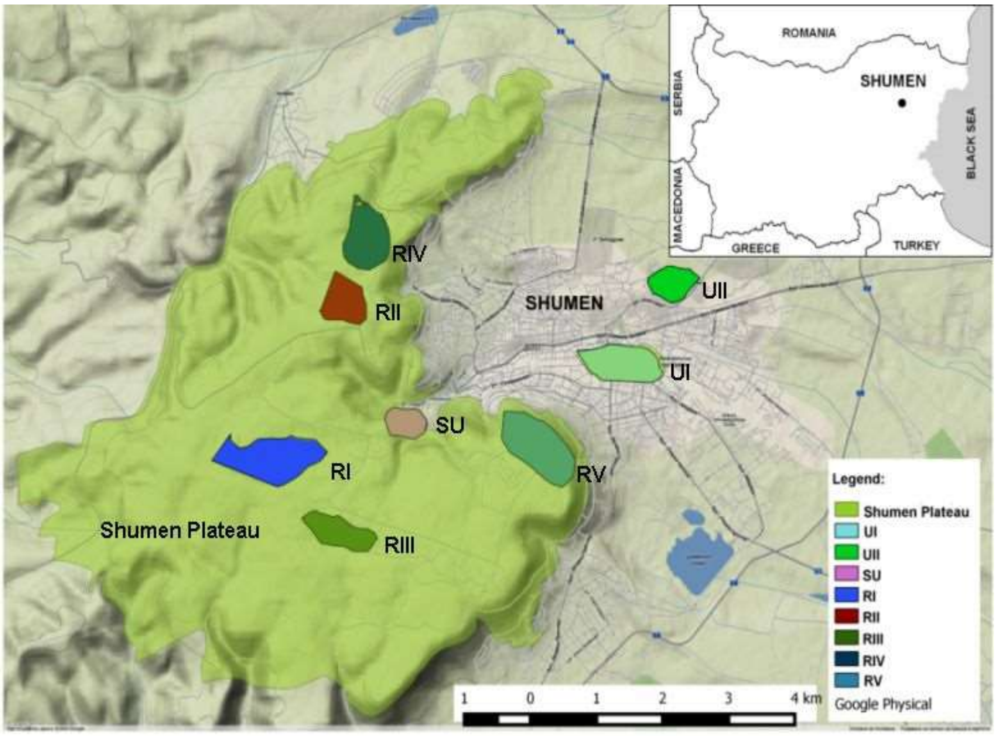

Figure 1. Map of research area showing the location of the collecting sites

Site description:

RI: Theromophilic Moesian beech forest [20], with presence also of *Carpinus betulus* L., 1753, *Quercus dalechampii* Ten., *Quercus frainetto* Ten. (1813), *Quercus cerris*Linnaeus, 1753, *Tilia tomentosa* Moench, etc. Scrubfloor does not form almost anywhere. The participation of several types of xerophilic species from the neighboring oak and hornbeam forests, such as *Glechoma hederacea* L., *Hedera helix* Linnaeus, 1753, *Lathyrus laxiflorus* (Desf.), *Melissa officinalis* Linnaeus, 1753, *Mercurialis perennis* L., *Milium effusum* L., *Muscari botryoides* Mill, *Polygonatum latifolium* (Jacq.) Desf., *Ruscus aculeatus* Linnaeus, 1753, *Tamus communis* (Linnaeus), 1753, *Viola riviniana* Rchb., etc. Dominants for the grasssynusia are *Rubus hirtus* Waldst. & Kit., *Poa nemoralis* L., *Brachypodium sylvaticum* (Huds.) Beauv., *Galium odoratum* (L.) Scop., 1771, *Festuca heterophylla* Lam., *Lamiastrum galeobdolon* (L.) Ehrend. & Polatschek, *Sanicula europaea* Linnaeus, 1753, *Cyclamen coum* Mill and *Carex sylvatica* Huds. Category according to EUNIS habitat classification: G1.661. Geographical coordinates: N 43°15′592′′;E 26°53′310′′.

RII: Located at the border of coniferous and deciduous hornbeam-Sessile oak forests. In a relatively equal amount are found the following tree species: *Fagus sylvatica* Linnaeus, 1753, *C. betulus*, *Pinus nigra* J. F. Arnold 1785, and *Pinus sylvestris* (Linnaeus, 1758). The scrub

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floor resembles that of the coniferous forests and includes representatives of *Rosa* sp., *Crataegus monogyna* Jacq., 1775, *P. spina-christi* and not as often of *Fraxinus ornus* Linnaeus, 1753. Grass synusia is composed primarily of xerophytic species, such as *H. helix*, *M. botryoides*, *G.hederacea*, *V. riviniana*, etc. Category according to EUNIS habitat classification: G3.F12+G1.A32+G1.6. Geographical coordinates: N 43°16′502′′;E 26°53′376′′.

RIII: Besides the dominant species *C. betulus* and *Quercus petraea* (Matt.) Liebl., 1784 in the composition of the tree floor there are also *F. sylvatica*, *C. orientalis*, *Q. frainetto*, *Q. cerris* and *Populus tremula* Linnaeus, 1753. The scrub synusia is composed of *C. monogyna* and *Corylus avellana* L. (1753) and less often of *F. ornus*. Except for *Lamiastrum galeobdolon* (L.) Ehrend. & Polatschek, the other major dominants among the grasses are *P. nemoralis*, *B. sylvaticum*, *F. heterophylla* and *Melica uniflora* Retz.. Category according to EUNIS habitat classification: G1.A322. Geographical coordinates: N 43°14′605′′;E 26°54′618′′.

RIV: This sampling site is located in a coniferous forest, which is composed mainly of a pure culture of *P. nigra*. The coniferous forests in the Shumen Plateau occupy about 16% of its territory and are composed of artificially introduced tree species. The scrub floor is composed of *Rosa* sp., *C. monogyna*, and not as often of *Prunus spinosa* L.. Category according to EUNIS habitat classification: G3.F12. Geographical coordinates: N 43°16′791′′;E 26°53′562′′.

RV: Depending on its phytocoenological outlook, the site can be divided into two parts. Its eastern half belongs to the xerophytic grasslands, which on the territory of the Shumen Plateau refer to the phytocoenose *Festuco-Brometea*. These phytocoenoses occur at places where forests have been destroyed in the distant past. Now they compose only aminor part of the plant cover in the Nature park (0.6%). The western part of site is occupied by low shrub phytocoenoses of the *Prunetum tenellae* association, which have only a symbolic participation (0.08%) in the vegetation cover of the Shumen plateau. These secondary communities are found on eroded landscapes along with *S. vulgaris*, *P. spina-christi*, *P. spinosa*, *C. orientalis* and xerophilic grasslands. Category according to EUNIS habitat classification: E1.2. Geographical coordinates: N 43°15′504′′;E 26°55′599′′.

SU: The site is located in semi-natural formation, strongly influenced by the human activity. There are no dominant species, although horse chestnut, *Aesculus hippocastanum* Linnaeus, 1753, is quite common. Well represented are also: *T. tomentosa*, *Acer campestre* L., *Acer* and *Juglans regia* Linnaeus, (1753). Scrub floor is very scanty and represented by ornamental species, such as *H. helix*. In the grass synusia there are representatives of *Parietaria officinalis* Linnaeus, 1753, *Dactylis glomerata* Linnaeus, 1753, *Geum urbanum*L., *Geranium* sp., *Ballota nigra* L., *Vinca minor* L., *Chaerophyllum temulentum* L., etc. Geographical coordinates: N 43°15′927″; E 26°54′028″.

UI:Wet meadows in highly urbanized spaces – small parks, public squares and around the streets. There are no clearly dominant species. Phytocenoses are represented by *A. hippocastanum*, *Amorpha fruticosa* Linnaeus, 1753, *Platanus orientalis* Linnaeus, 1753, *Prunus mahaleb* Linnaeus, *T. tomentosa*, *A. campestre*, *Cercis siliquastrum* L., *Bellis perennis* L., *Lolium perenne* L., *Taraxacum officinale* F. H. Wigg., *P. officinalis*, *G. urbanum*, etc. Geographical coordinates: N 43°16′260′′; E 26°56′403′′.

UII: The site is located near the University of Shumen, which is heavily urbanized, with several sport facilities (a football field and two tennis courts), three parking lots, a number of

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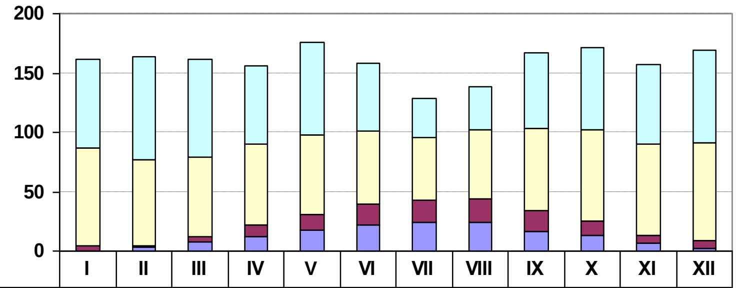
buildings, alleys and lawns. The total surface of the area amounts to 180 ha. In terms of habitats it can be divided into two parts. The northeast part is composed of mixed plantations of park type, where the most numerous spicies are *P. nigra*, *T. tomentosa*, Robinia pseudoacacia L., *A. hippocastanum* and *C. siliquastrum*. The scrub floor is relatively scanty and grass sinusius is formed by *H. helix*, *Clematis vitalba* Linnaeus (1753), *Salvia nemorosa* L., *Galium aparine* L., *Poa pratensis* L., *C. bursa-pastoris*, *T. officinale*, *Malva sylvestris* L., *Silene vulgaris* (Moench), etc. The southwestern part of site encompasses meadows with individual trees and shrubs. Geographical coordinates: N 43°16′750′′;E 26°56′870′′.

In the period of research the average annual temperature of air in the higher parts of the Shumen Plateau was 8-10°C while in the lower eastern parts and in the city area they were 11-12°C. In the last few years we have been observing a trend of increase in the temperature, and based on the data from the meteorological station in Shumen, the year 2008 has been the warmest one until now with an average annual temperature of 12.5°C. Negative temperatures were registered in the end of December 2007 and in the first half of the month of January 2008 which was in contrast to the winter of 2008-2009 when there were no registered temperatures below 0°C (Fig. 2).



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Humidity of soil	75,62	86,75	81,41	66	78,45	57,32	33,79	35,98	63,97	68,63	67,41	78,46
Humidity of air	82,5	72,25	67	67,5	66,5	61	52,5	58,5	69,5	77	77	82
Soil temperature	3,96	1,17	5,29	10,32	13,7	18,05	18,84	20,15	16,9	12,39	6,81	6,53
Air temperature	0	3,1	7,3	11,85	17,2	21,8	23,85	23,9	16,75	12,95	6,1	2,65

Figure 2. Average monthly values of air and soil humidity (%) and air and soil temperature (°C) (based on data from the Meteorological station, Shumen)

In the bigger part of the study precipitation in the region was scarce – to 50l/m^2, except in fall and winter (from the second half of August to the beginning of January) and a few weeks in May and June when it reached 100 l/m^2 (Fig. 3). In the period October-November due to heavy rains there were measured 150 l/m^2.

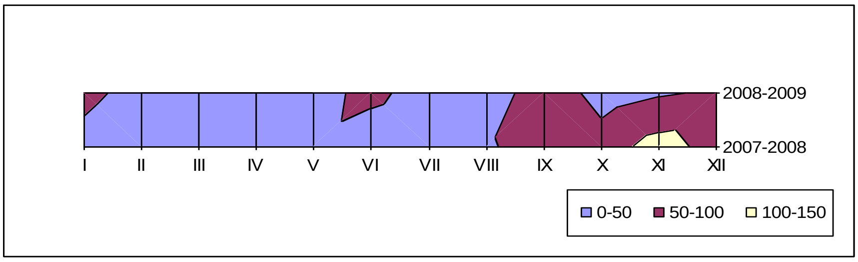


Figure 3. Average monthly amount of precipitation for the period 2007-2009 in l/m^2 (based on data from the Meteorological station, Shumen)

The material was collected through pitfall traps – 10 in each sampling site, arranged in a straight line and at a distance of 10 m from each other, reported on a monthly base in the period May 2007 – May 2009. As one can catch only active individuals using pitfall traps [5, 15], the catch can be interpreted more as an indication of the species' activity rather than as a measure of their density [6]. In order to define the modes of activity of the different species and in order to study the possible influence of the climatic factors on these models, it is recommended that the collection of material is done within the span of at least a year [3]. In this study our observations have been conducted within the span of two years which complies with the requirement stated herewith.

The influence of the main factors of the environment – temperature and humidity of the soil and air on the surface activity of *L. nigripalpis* is rendered through a correlation analysis between the average values of the parameters of the environment in months and the number of caught individuals, defining at the same time the standardized coefficients of Pearson-Brave. In order for the seasonal activity of the species to be modelled by the factors of the environment which were tested, a regressive analysis has been used checking the adequacy of the acquired models as well as the statistical significance of the coefficients (R and R^2) used in the used equations of regression. The software packages SPSS 9.0 and Stat Plus 3.5.3 have been used.

RESULTS

L. nigripalpis was found in all investigated areas, with a total of 707 specimens collected. The highest number of specimens (157) was established in the open meadow (RV), and the lowest (28) – in the suburban area (SU) (Table 1, Fig. 4).

Table 1.Total number of specimens collected in the period May 2007 – May 2009 by months and sites

Month	Collecting sites							
	UI	UII	SU	RI	RII	RIII	RIV	RV
January		4						1
February	4	3						2
March		7		1	5	2		2
April	13	5		3	1	1	1	3
May	11	3	2	1			9	6
June	4	2	3	5	6	4	1	14
July	19	17	9	27	24	10	41	63
August	23	17	6	35	45	14	34	36
September	5	8	3	11	10	1	14	15
October	9	12	5	3	3	2	2	2
November	4	11		2	4	1	2	9
December	2	9		1	3		1	4
Total:	**94**	**98**	**28**	**89**	**101**	**35**	**105**	**157**

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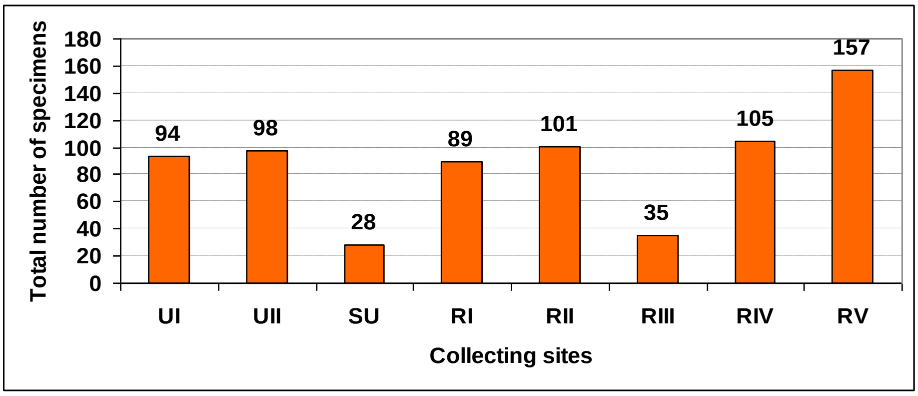

Figure 4. Distribution of *L. nigripalpis* in the period May 2007 –May 2009 by collecting sites

The data from the preliminary *Least Significant Difference* (LSD) analysis show highest results variation at RV (*Std. Deviation*=11.221) and significant differences in the distribution of the species while comparing SU and RV (p=0.007) and RIII and RV (p=0.01) (Table 2).

Table 2. Results from the dispersion analysis of the data on the distribution of *L. nigripalpis* in months

	N	*Sum*	*Mean*	*Std. Deviation*	*Std. Error*	*95% Confidence Intervalfor Mean*		*Min*	*Max*
						Lower Bound	Upper Bound		
UI	24	94	3,625	4,950	1,010	1,535	5,715	0	18
UII	24	98	4,083	3,243	0,662	2,714	5,453	0	13
SU	24	28	1,167	1,949	0,398	0,344	1,989	0	7
RI	24	89	3,667	6,838	1,396	0,779	6,554	0	29
RII	24	101	4,208	7,524	1,536	1,031	7,385	0	34
RIII	24	35	1,417	2,358	0,481	0,421	2,412	0	7
RIV	24	105	4,375	9,15	1,868	0,511	8,239	0	37
RV	24	157	6,458	**11,221**	2,29	1,72	11,197	0	50
Total	192	707	3,625	6,749	0,487	2,664	4,586	0	50

The highest activity of the species is registered in July and August when the highest temperatures and least precipitation were reported (Figs. 2, 3, 5).

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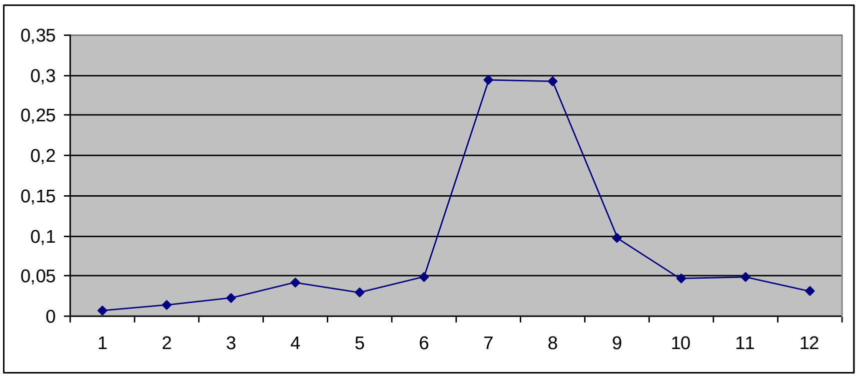

Figure 5. Empirical relative density of distribution of *L. nigripalpis* in months in the period May 2007 –May 2009

The seasonal activity of *L. nigripalpis* has been analyzed through evaluation of specimens abundance and the average values of environment parameters, with the standardized coefficients of Pearson-Brave being calculated. A statistically significant dependence of species activity on three of the studied factors of the environment – humidity of soil, air and soil temperatures has been established (Table 3).

The coefficient of correlation of the species activity and soil humidity (-0.847) has the highest absolute value. The negative value reflects the trend of reduction in the numbers and terrestrial activity of the species with the increase in soil humidity. The coefficients of correlation between the activity of *L. nigripalpis* and respectively air temperature (0.700) and soil temperature (0.742) have close positive values as the species' activity increases with the increase of their values.

The strong correlation between the abiotic factors of the environment impedes the development of a sufficiently reliable general model of the seasonal activity of *L. nigripalpis*. Different regression models were used to analyze the dependence of the relative number of specimens caught in months (Y) on the statistically significant factors of the environment (X) (Table 4). The empirical and theoretical values of F show that these models are adequate ($Sign.F<\alpha=0.05$) and that the coefficients of determination R^2 in the used equations of regression are statistically significant.

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Table 3. Correlation coefficients of Pearson-Brave for *L. nigripalpis*

* Correlation is significant at the 0,05 level (2-tailed).

** Correlation is significant at the 0,01 level (2-tailed).

Factor	*Correlations*	Air temperature (°C)	Soil temperature (°C)	Humidity of air (%)	Humidity of soil (%)	Total number of specimens
Air temperature (°C)	PearsonCorrelation Sig. (2-tailed) N	1 , 12	0.953** 0 12	-0.713** 0,009 12	-0.760** 0,004 12	**0.700*** 0,011 12
Soil temperature (°C)	PearsonCorrelation Sig. (2-tailed) N	0.953** 0 12	1 , 12	-0.617* 0,033 12	-0.793** 0,002 12	**0.742**** 0,006 12
Humidity of air (%)	PearsonCorrelation Sig. (2-tailed) N	-0.713** 0,009 12	-0.617* 0,033 12	1 , 12	0.740** 0,006 12	-0,555 0,061 12
Humidity of soil (%)	PearsonCorrelation Sig. (2-tailed) N	-0.760** 0,004 12	-0.793** 0,002 12	0.740** 0,006 12	1 , 12	**-0.847**** 0,001 12
Total number of specimens	PearsonCorrelation Sig. (2-tailed) N	0.700* 0,011 12	0.742** 0,006 12	-0,555 0,061 12	-0.847** 0,001 12	1 , 12

Table 4. Summary of the results from the regression analysis on the seasonal activity of *L. nigripalpis* from the statistically significant factors of the environment

Factor	Regression equation	Coefficients		*Sign. F*
		Regression coefficient	Coefficient of determination	
Humidity of soil (X)	$Y = e^{(b_0 + b_1 / x)}$ const. b_0= -5.64 const. b_1= 147.7	R =0.826	R^2 = 0.6966	*Sign. F*=0.0007
Air temperature (X)	$Y = b_0 (b_1)^x$ const. b_0= 0.01 const. b_1= 1.1	R =0.843	R^2 = 0.7107	*Sign. F*=0.006
Soil temperature(X)	$Y = b_0 (b_1)^x$ const. b_0= 0.01 const. b_1= 1.16	R =0.8825	R^2 = 0.7789	*Sign. F*=0.0001

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The regressive coefficients: R=0.826 (for soil humidity), R=0.843 (air temperature) and R=0.8825 (soil temperature) and the relevant coefficients of determination: R^2=0.6966, R^2=0.7107 and R^2=0.7789 show that the bigger part of the variation in relative frequencies (69.66 %, 71.07% and 77.89%) is due to regression. The rest of the variation is due to factors which have not been included in the models. As the value of *Sig.T* in all models are lower than 0.05, the coefficients in the regression equations are statistically significant (Table 5, column (6)).

Table 5. Values and statistical significance of coefficients in the studied regression models

Factor	*Variable* (1)	*B* (2)	*SE B* (3)	*Beta* (4)	*T* (5)	*Sig. T* (6)
Humidity of soil	*X*	147.716958	30.605237	0.836455	4.827	**0.0007**
	constant	-5.642200	0.562812		-10.025	0.00
Air temperature	*X*	1.106166	0.022521	2.323338	49.117	**0.000**
	constant	0.010764	0.002797		2.818	0.0182
Soil temperature	*X*	1.164247	0.029830	2.417067	39.030	**0.000**
	constant	0.01	0.003610		3.090	0.0114

In the region of research *L. nigripalpis* exhibits highest activity in summer – from June to September. A peak in the terrestrial activity of the species is reported in July and August at relatively low values of soil humidity – up to 30-40%, soil temperature of 10°-20°C and air temperature of above 25°C (Fig. 6 A, B, C).

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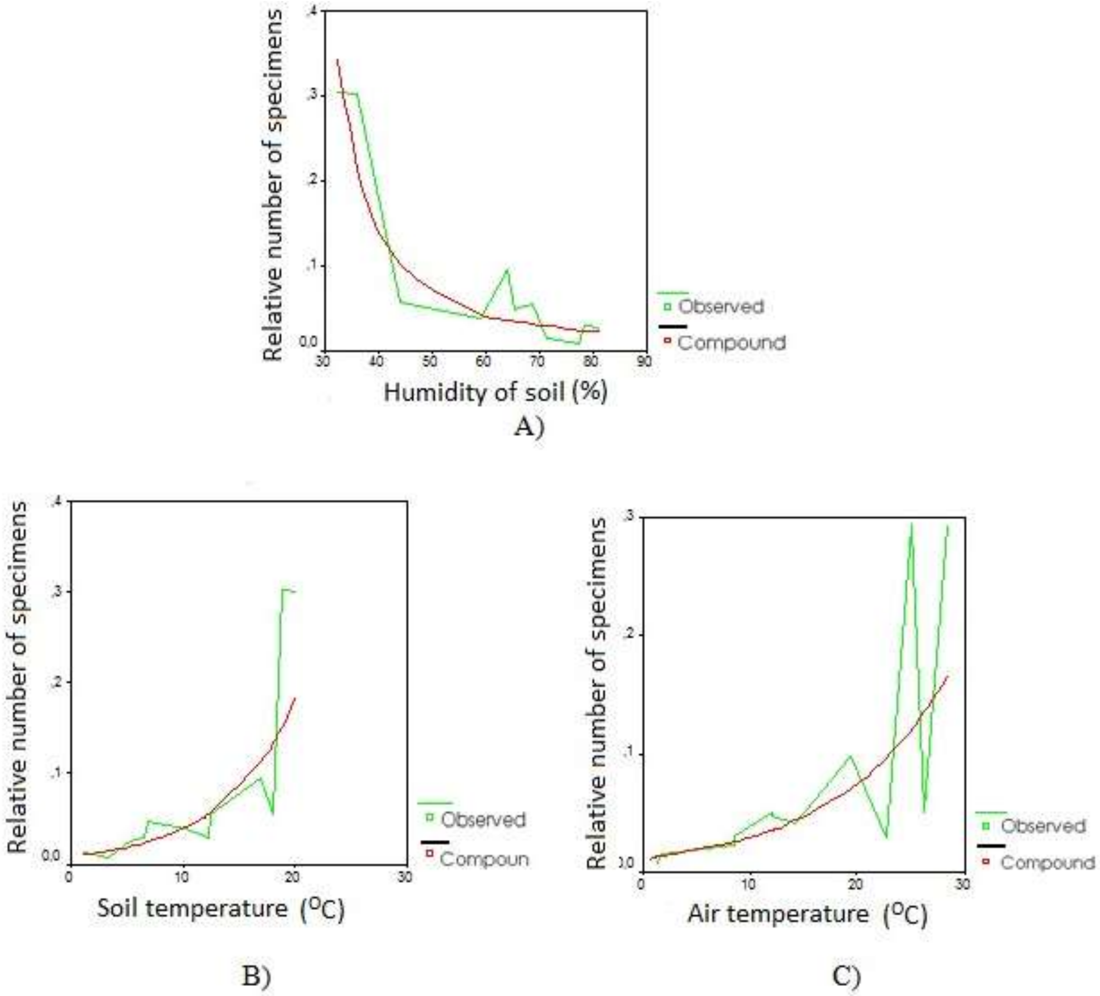

Figure 6. Empirical and evaluated densities of distribution of *L. nigripalpis* from the statistically significant factors of the environment

DISCUSSION

The study revealed that in the studied region*L. nigripalpis* is euryoecious species confined to a range ofhabitats: from highly urbanized city parks of Shumen to natural deciduous, coniferous, and mixed woods and open areas of Shumen Plateau. Our results complete the data available up to the moment on the general distribution of the species in Bulgaria, Turkey, and Greece [17, 24, 26]. The current levels of urbanization of the city do not seem to have any significant effect on the distribution and activity of the species concerned. Its presence in the city greens (UI and UII) is comparable to that in the rural habitats (RI, RII and RIV) (Table 1). However, it demonstrates clear preference forundisturbed openhabitats, in particular xerothermic shrubby grasslandsof the phytocoenose *Festuco-Brometea*, where the lowest values of air and soil humidity and the highest temperatures were reported. The dominance of *L. nigripalpis* in the open habitats is connected with its increased resistance to drought [1, 9, 10, 25] and confirms its preference to drier open and steppe habitats (meadows and pastures) [24].

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The results from our study show that the factors of the environment with the most significant and positive influence on the activity of *L. nigripalpis* are air temperature and soil temperature and the increase in their values leads to a reciprocal increase in the activity of the species (Fig. 6 B, C). At the same time, the analysis of the data shows that the activity of the species correlates statistically significantly, however, inversely with soil humidity. The increase in precipitation and soil humidity leads to a reduction in the number and in the intensity of surface activity of *L. nigripalpis* (Fig. 6A). Thus, the data obtained by us only partially confirm the assumption made by Auerbach [2] that the increased level of rainfall and the increase of air temperature are the factors of the environment which determine the higher density in the Chilopoda populations to the greatest degree.

The peak in surface activity of *L. nigripalpis* in summer could be associated with the possibility that it coincides with its breeding period. At that time adult individuals become active in their search for a mating partner or places suitable for hatching. However, bearing in mind the lack of information on the phenology of the specific species, such kind of assumed correlation between *L. nigripalpis'* activity and the breeding strategies of the species can be considered as rather speculative in nature.

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