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RESEARCH ARTICLE

Lumbricides as a bio-indicators of the influence of electrical transmission line in the conditions of Ukrainian Polissia

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Abstract

The complex interaction of a man and the environment requires the creation of algorithms for predicting the effects of anthropogenic impact. This requires the creation of the ecosystem models where all their basic elements and relationships are taken into account. One of the most effective methods for choosing the most informative differential elements of a system is the development and the implementation of bio-indication models. Nowadays the important task is the development of the bio-indication methods for various anthropogenic complex effects.

The electrical transmission lines carry out a specific integrated environmental impact. It is created on the changes in the environment under the influence of magnetic and electric fields and the long-term consequences of their interaction with ecosystem components. This effect is negative for the most representatives of biota and for earthworms in particular. We observe how the number of species decreases, the species diversity reduces and the morphological parameters change towards species with a shorter body length under reaching the electrical transmission lines.

Some genera of the earthworms are able to survive under the effects of the modern electrical transmission lines, although this reflects their abundance and morphological parameters. These species include *Aporrectodea caliginosa* and *Aporrectodea trapezoides*. They can be used as diagnostic genera of impact of the electrical transmission lines on biota. They can be genera indicators for the determination of the effect of the electrical transmission lines. The presence of *Lumbricus terrestris* shows the low electrical transmission line effects, and the presence of *Aporrectodea rosea* or *Aporrectodea longa* shows low or moderate effects.

We can create bioindication models according to the relations between groups of species of dominant and subdominant specimens formed by the body size. Under the condition of creating a wide data-

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base and establishing the vitality parameters, it is possible to develop more advanced and efficient algorithms for the synbioindicator analysis of the impact of the electrical transmission lines on the environment.

Keywords
biodiversity, environmental modeling, human impact, electrical fields

Introduction

The environment is a complex and a difficult to predict system. Human activity causes constant changes with a difficult to predict consequences (Khomiak 2012). This may constitute a threat to the future of local ecosystems and the biosphere as a whole. A human is an integral part of the biosphere and depends on the optimality of the factor indicators that have formed in it. The changes of these factors can lead to a deterioration in the quality of life and even lead to our extinction (Khomiak et al. 2018, Khomiak 2018).

Predicting of the dynamics of complex systems as ecosystems is a huge challenge (Khomiak et al. 2019). The models used for them do not always give a good result. Every theorist who is trying to create a perfect model faces a problem that has been described by Edward Lorenz, who worked on the weather forecast in 1961. The result can do depend on the initial conditions, and any least influence will completely change it. However, unlike the atmosphere or other abiotic systems, the ecosystems are self-regulating. Besides, their dynamics will be more predictable. At the same time the diversity of connections in ecosystems is much higher. This means that any of them can become crucial. Since we cannot reflect the entire complexity of the ecosystem and all the characteristics of the starting conditions in our models, we must carefully select those that are basic.

Thus, we recognize the impossibility of an accurate prediction of the dynamics of the complex systems, but accept the need. The accumulation of data on the reaction of various groups of organisms to a complex of anthropogenic changes makes our prediction more accurate, and, therefore, protects us from the negative consequences of our own activities. A guarantee of the desired prediction work is the fulfillment of several requirements for the models on the basis of which it is created. There are two opposite attitudes towards the practical implementation of the ecosystem models (Schuwirth et al. 2019). Some believe that any model can be successfully used, while others believe that none of them is suitable for practical environmental management. First of all, the theoretical foundations on which this model is created are well calculated. It should be aimed at a practical use and adapted to the issues of the environmental transformation management in specific spatial-temporal conditions. Moreover, the probability of the prediction should be numerically expressed and sufficient for the practical use (Schuwirth et al. 2019).

More often the groups of autotrophic organisms are included in the model, and it is really reasonable. It is they which form energy flows in the ecosystems and is a bridge between ecotopes and biocenosis. Sometimes such models include a human activity, the behavior of rare components of the biota, and the population characteristics of individual animals. Sometimes such animals can indeed be key elements of ecosystems. The important place among them is occupied by the representatives of pedofauna (for example, Lumbricides), which take part in the soil formation, becoming the second important link that unites the living and non-living components of the ecosystems. Thus, these organisms close numerous flows of substance and energy on themselves. The environmental factors that are modified by humans can have a versatile effect on earthworms. This can lead to the changes in the entire ecosystem as a whole or in its individual components.

However, Lumbricidae are the bioindicators of the complex environmental changes. Since we cannot completely calculate all possible complex effects on the human body, the reaction of this group of organisms can be an important warning of a possible danger (Khomiak 2012).

One of the key characteristics of the civilization is its manipulation of energy. The more the civilization development reaches, the greater masses of energy it has to transport from one place to another. It is necessary not only to increase the power of the electrical transmission lines, but to expand their network as well. Nowadays, the main type of energy used by the civilization is electricity. The transportation is accompanied by certain changes in the environment. First of all, we are talking about the magnetic fields and electric potentials in the area of the electrical transmission lines. Lumbricides are under the constant influence of these factors, therefore, the changes in their population characteristics can serve as one of the indicators for creating of models for predicting the impact of the electricity transportation on the environment. Moreover, they are quite a convenient object for their low mobility. Unlike plants, most of which can be used as bioindicators only during the period of mass vegetation, the earthworms are constantly available for a study (Khomyak et al. 2016).

At the first stage of the research, the parameters that are laid down in the ecosystem model are the abundance and species diversity of this group of animals. Later on, it will be possible to proceed to the study of the population genetic characteristics, paying attention to the small deviations in the biochemical balance of the organisms of individual species.

Material and methods

The collection of the material was carried out in the territory of Ukrainian Polissia in 2017–2018. 880 specimens of the earthworms of the family Lumbricidae belonging to three genera were collected: *Aporrectodea* (*A. trapezoides* (Dugesi, 1828), *A. longa* (Ude, 1885), *A. rosea* (Savigny, 1826), *A. caliginosa* (Savigny, 1826)); *Lumbricus* (*L.*

terrestris (Linnaeus, 1758)); *Octolasion* (*O. lacteum* (Öerley, 1885)). The collection of the material was carried out according to the standard methods. The soil samples in areas of 0.5 m^2 were taken in layers. The thickness of each layer is 10 cm. The maximum depth of the sample was determined by the presence of the earthworms. The soil moisture type was determined when sampling. The humidity is according to the gradation of humidity degrees: dry, slightly moistened, moist, nasty, and wet (Pohrebniak 1993). We define plant communities by the Brown Blanke method (Khomyak et al. 2016). The samples were taken every 50 m from the electrical transmission lines to a distance of 200 m using the method of excavation and separation of the soil by hand. The voltage in the electrical transmission lines is about 400 kV. The samples were taken under the same environmental conditions.

The intensity of pigmentation of the integument and girdle was determined on the living material (Vlasenko 2008, 2018; Vsevolodova-Perel 1988). The worms found in the soil were fixed,previously washed from the mucus and the parts of the earth adhering to it. 70% ethanol mixed with glycerol was used as a fixer. The fixed worms were used for the morphological studies.

Only sexually mature species were used for the study. The species identification was carried out according to guide tables provided in the papers of T. S. Perel (1975, 1979) with additions (Vsevolodova-Perel 1988, Vlasenko 2008).

Under the morphometry, the following parameters were examined: the body length (L) and the girdle (l_2), the distance from the main lappet to the first segment of the girdle (l_1), the body diameter (D) in the out-of-girdle zone. The total number of the segments (n) and the number of segments to the girdle (n_1), the topography of the bristles, the position of the dorsal pores and papillomas, the size, the shape and the location of the girdle and puberal ridges were determined using a binocular magnifier. Besides the following was used: the ratio of the average sizes of segments in the girdle (l_1/n_2), and a number of indices characterizing the relative sizes of the body (L/n, l_1/n_1, D/L, D/l_1, l_1/L, l_2/L, l_2/l_1).

To calculate the indicators of the dominance of the diversity, a package of applied statistical programs PAST was used (Paleontological Statistics for education and data analysis) (Hammeret al. 2001).

Statistical processing of materials was carried out using the package of applied statistical programs STATISTICA 6.0. When working with animal objects, the principles of biological ethics were taken into account (Goldim 2009).

Results

880 species of earthworms were found (Table 1) in the selected soil samples. Among them are 880 mature animals that account 84.5% of the total. Discovered species belong to six species from the three genera. The genus *Aporrectodea* was most widely represented, that is four species. 791 specimens of its representatives were found in the samples and accounts 89.9%. Among species of the genus, the greatest number

Table 1. The abundance of identified genera of *Lumbricidae* in the total sample.

Genus	Specimens quantity	Total number of specimens
A. trapezoids	232	880
A. rosea	12	
A. longa	24	
A. caliginosa	523	
L. terrestris	4	
O. lacteum	85	

of specimens is observed in *A. caliginosa* (523 specimens) and *A. trapezoides* (232 specimens). The smallest amount is in *A. rosea* (12 specimens) and *A. longa* (24 specimens).

The genera *Lumbricus* and *Octolasion* are represented by only one specimen for each, 4 and 85 specimens, respectively (Table 1).

The ratio between the numbers of specimens in each species doesn't match their degree of dominance in the separate experimental plots (Table 2). Thus, the most abundant species *A. caliginosa* dominates in three of the four plots and another subdominant is in one of them. The second largest species, *A. trapezoides* dominates in one area and is a subdominant in two of them. *O. lacteum* is the third largest number of species in another subdominant area.

A number of each species varies individually at different distances from the electrical transmission lines (Vlasenko 2007, Vlasenko and Baranovska 2009, Vlasenko and Pika 2015). Only three species of *A. caliginosa*, *A. trapezoides*, and *O. lacteum* are found directly under the electrical transmission lines. These are the most widespread species belonging to dominant (96% of specimens) and subdominant (4%) ones. All representatives of the studied species appear only at a distance

Table 2. The species structure of *Lumbricidae* complexes of the studied plots.

Settlement (date of sampling)	Total Quantity of Specimens	Species Diversity	Dominant Species	Subdominant Species
v. Khotyn (03.11.2017)	70	6	*A. trapezoides*	*A. caliginosa*
v. Prysluch (5.06.2018)	106	4	*A. caliginosa*	*A. trapezoides*
v. Khotyn (15.08.2018)	487	5	*A. caliginosa*	*A. trapezoides*
v. Mokvyn (23.09.2018)	217	3	*A. caliginosa*	*O. lacteum*

of 200 m, and the share of dominant among the found specimens is reduced to 81%. *L. terrestris* appears the last in the samples. The total number of species of the earthworms also varies from 48 to 317 specimens (Table 3). Thus, only 4.6% of species are directly under the electrical transmission line, while 30.4% of then are at a distance of 200 m that is 6.6 times higher.

In addition to the changes in abundance and species diversity under the influence of electrical transmission lines, certain changes in morphological parameters are observed (Kronet et al. 2007, 2010, 2013; Roshko 2010). One of the most mark able changes is a change in the body length. The closer to the electrical transmission line is, the narrower the variability of this parameter. This reaction is similar to the reaction of angiosperms to a similar complex of factors.

Whereas not all species are able to be in close proximity to the electrical transmission lines, the analysis of the changes in morphological parameters was carried out for dominant and subdominant species of Lumbricidae, that is *A. caliginosa* and *A. trapezoides*. For example, *L. terrestris* is found only in small quantities at a distance more than 200 m. The specimens of the dominant species *A. caliginosa* with body lengths ranging from 50 to 95 mm were found directly under the electrical transmission lines. This morphological indicator increased at a distance of 200 m; the species of 80 to 125 mm long can be met (Fig. 1).

A similar indicator of the subdominant species of the earthworms *A. trapezoides* varies on the average from 55 mm to 100 mm under the electrical transmission lines (0 m) and from 80 mm to 125 mm under the control (200 m) (Fig. 2).

Table 3. The main indicators of the abundance of earthworms depending on the distance to the electrical transmission lines.

Genus	**Distance (m)**				
	0	50	100	150	200
	Abundance (spec./m^2)				
A. caliginosa	37	78	99	139	170
A. trapezoides	9	23	43	70	87
A. rosea	-	-	-	5	7
A. longa	-	-	5	4	15
L. terrestris	-	-	-	-	4
O. lacteum	2	7	14	28	34
Total Quantity of Specimens (*N*)	48	108	161	246	317
Genera Quantity (*S*)	3	3	4	5	6
Share of the dominant species (*A. caliginosa, A. trapezoides*), (%)	96	93	88	85	81

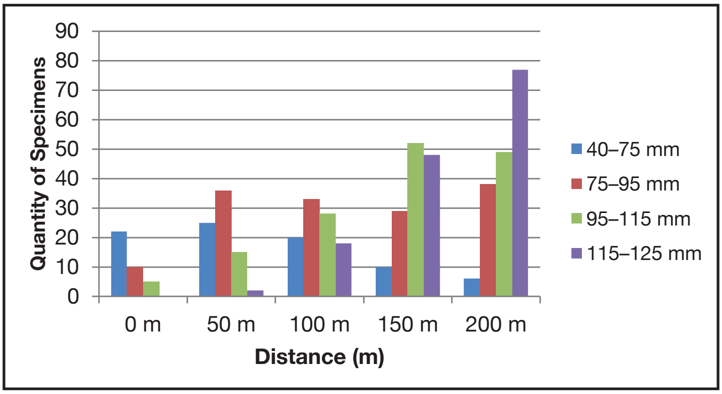

Figure 1. Variations of the body length of *A. caliginosa* depending on the distance to the electrical transmission lines.

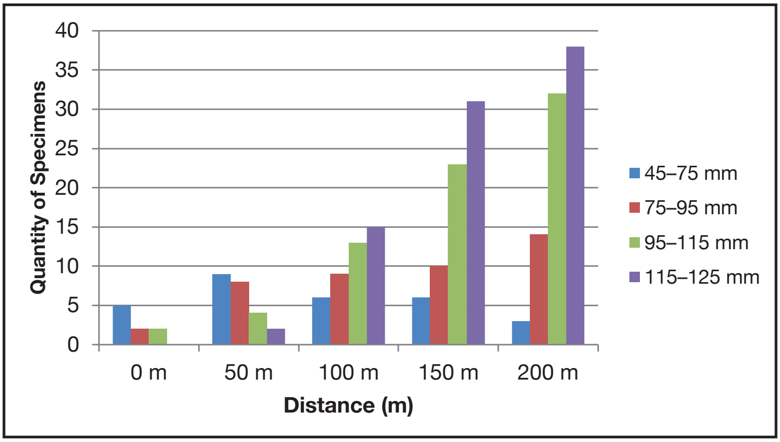

Figure 2. The body length of *A. trapezoides* depending on the distance to the electrical transmission lines.

Discussion

The analysis of the morphological indicators, the abundance, and the species diversity shows the negative influence of the factors generated by the high voltage electrical transmission lines that agree quite well with the data obtained by other scientists (Bankoske 1980, Aleksandrov 2011). This is confirmed by most indices of the α-variety that we calculated (Table 4).

Such a reaction does not allow using of the earthworms as bioindicators of different levels (Didukh 2012).Using the eurytopic dominant worm species of *A. caliginosa* and *A. trapezoides*, we can determine the influence of a complex of the factors generated by the electrical transmission lines for the variations in the body length. It is possible under the presence of a certain ratio of the species with a maxi-

Table 4. Indices of α-variety of the earthworms depending on the distance to the electrical transmission lines.

Indices of α-variety	Distance (m)				
	0	50	100	150	200
Taxa_S	3	3	4	5	6
Individuals	48	108	161	246	317
Dominance_D	0,63	03,57	0,46	0,41	0,38
Simson_1-D	0,37	0,43	0,54	0,59	0,62
Shannon_H	0,65	0,74	0,97	1,07	1,21
Evenness_e^H/S	0,64	0,74	0,97	1,07	1,21
Brilouin	0,58	0,7	0,93	1,04	1,18
Menhinick	0,43	0,29	0,32	0,32	0,34
Margalef	0,52	0,43	0,59	0,73	0,87
Equitability_J	0,59	0,68	0,7	0,67	0,68
Fisher_alpha	0,71	0,57	0,74	0,89	1,05
Berger-Parker	0,77	0,72	0,61	0,57	0,53

mum body length. For example, the ratio of groups of species with a certain body length of *A. trapezoides* changes on a regular basis every 50 meters. The share of the ones with maximum sizes is growing, and ones with small sizes are falling. That is, a group of the species with a body length of 115–125 mm has the following ratio: 0%; 9%; 44%; 44%. It means that the species with such parameters are not found directly under the electrical transmission lines, and their ratio does not change starting from a distance of 150 m. The ratio of the species with a minimum length (45–75 mm) is characterized by a different distribution: 56%; 39%; 14%; 9%; 3%. Even expanding the range of measured parameters, we can obtained a regular change of these indicators. For example, the ratio of a group of the species with a body length of 45 to 95 mm varies as follows: 77%; 74%; 35%; 25%; 20%. Thus, having determined the ratio of the species with certain body sizes for dominant and subdominant species, we can determine the complex environmental impact of the electrical transmission lines.

If we observe abnormal changes in the ratios of the number of the species at a certain distance, it can be a signal for the existence of the certain deviations of indicators of the factors of the natural or anthropogenic environment. That is, it can be changes of the edaphic, microclimatic or orographic factors. However, if there are no obvious abnormalities, this may reflect the possible accidental impacts of the electrical transmission lines caused by the violations of its structure or operation. In this case, we are talking about the prolonged repeated exposure. This makes it possible to use the bioindication method through the ratio of the worm sizes for the determination of the long-term emergency or pre-emergency state of the electrical transmission lines. The one-time instrumental monitoring is possible only at the moment of emission of the current electricity, under the changes in electrode potentials or magnetic fields. The bioindication allows monitoring longer and irregular changes.

In addition to the bioindication of the morphological parameters of species of the one genus, it's possible to use the bioindication of the highest level, i.e. species. The species with narrow ecological amplitude in the relation to a certain factor or to a complex of factors can be used as diagnostic (Didukh 2012). For example, the presence of *L. terrestris* indicates minor effects from the electrical transmission lines, and the presence of *A. rosea* or *A. longa* has a low or moderate effect. However, the species level of the bioindication gives quite high errors and has a number of other drawbacks. It requires the obligatory presence of the species-indicators in the studied area.

The synbioindication method is improved. Thus, we apply the analysis of the overlap of the vitality curves of the species included in the grouping (Didukh and Pliuta 1994).The error in determining the influence of the factor will be reduced to a few percent, as it happened during the transfer from the phytoindication to the synphytoindication, if there is a large database and a developed methodology of the objective vital indicators.

Conclusions

The electrical transmission lines have a negative effect on the biota and on the earthworms in particular. The number of the species decreases, species diversity decreases, and the morphological parameters change towards species with a shorter body length under reaching the electrical transmission lines.

There are species among the earthworms that are able to survive the effects of the modern electrical transmission lines, although this reflects their abundance and morphological parameters. These species include *A. caliginosa* and *A. trapezoides.*

Diagnostic species with narrow ecological amplitude in terms of the complex impacts of the electrical transmission lines are *A. rosea*, *A. longa* and *L. terrestris*. Moreover, the presence of *L. terrestris* shows minor effects from the electrical transmission lines, and the presence of *A. rosea* or *A. longa* shows a low or moderate effect.

The influence of the electrical transmission lines on the biota can be determined according to the relations between the size groups of genera of dominant and subdominant species. This allows using the bioindication method for both the study of the electrical transmission lines that operates in the normal mode and identifying or predicting the emergency situations that are irregular but long-term performance.

Subject to the creation of the wide database and providing of the vital parameters (using indices of diversity in body size or abundance), the algorithms for the synbioindication method for studying the environmental impact of the electrical transmission lines can be developed.We are planning to study the impact of power lines on a larger areas.

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