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Ecological and Faunistic Analysis of Lumbricidae Species Composition of Natural Biogeocenoses and Man-made Territories

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Abstract. Earthworms make up the bulk of the soil mesofauna and play an important role in the transformation of organic matter, the formation of the pedosphere, the regulation of the flows of matter, energy and information in ecosystems. In this research, we have studied the species composition of earthworms in urban and suburban ecosystems of the foothills of the Trans Ili-Alatau. As a result of the work, 11 species of the Lumbricidae family of the Oligochaeta class were discovered. 6 species out of them have been discovered in our Republic: *Aporrectodea rosea, Lumbricus rubellus, Lumbricus castaneus, Octolasion lacteum, Dendrobaena octaedra and Aporrectodea caliginosa* are widespread. The genus Lumbricus is the most common in terms of the number of individuals in the studied territories. Significant differences have been established in the species composition of earthworms in technogenic and natural biogeocenoses. The lumbricides are the absolute dominants in two ecosystems. Along with the species composition of earthworms, seasonal dynamics were also studied, it was found that their maximum activity is observed at the most favorable ratio of temperature and humidity.

Keywords: earthworms, ecological-faunal analysis, species composition, seasonal dynamics, Trans Ili-Alatau.

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Introduction

The soil, having a high absorption capacity, is the main accumulator, sorbent and destroyer of toxicants. The soil cover acts as a geochemical barrier to the migration of pollutants, protects adjacent environments from anthropogenic influences. However, the possibilities of soil as a buffer system are not unlimited [1, 2]. Thus, the accumulation of pollutants of various origins in the soil leads to a change in its chemical, physical and biological state, degradation and, ultimately, to the destruction. These negative changes are inevitably accompanied by the impact of soils, primarily on biodiversity, the productivity of the biotic component and the stability of biocenoses in general [3-5].

Currently, one of the vival environmental problems is the degradation of fertile black-earth soils, accompanied by a decrease in humus reserves. Earthworms are active soil generators that contribute to its accumulation and occupy a dominant position among soil-bearing invertebrates [6]. To increase the fertility of degraded black-earth soils, it is necessary to take measures to strengthen the role of these invertebrates, directly involved in the formation of the humus horizon of soils. In this regard, the study of the features of the formation of lumbricofauna in various biogeocenoses is an urgent problem of soil zoology [7]. Information on the fauna and ecology of earthworms is necessary to solve such practical problems as vermicultivation, supplementation of earthworms with the aim of their subsequent acclimatization during soil development to increase fertility, as well as to obtain biohumus in artificial conditions. However, the solution of these problems is hampered by insufficient knowledge of the species composition and ecology of earthworms in natural conditions [8].

Earthworm fauna in Kazakhstan are diverse in composition and consist of a number of endemic species confined mainly to mountain regions. However, the dynamics and biotopic distribution of the soil mesofauna of the territory of the Republic of Kazakhstan have not been fully studied and presented only in a few works (A.A. Sokolov, 1956; A.I. Novak, 2015) [9, 10].

The purpose of the work is to study the species composition, the ecological structure of lumbricofauna and the seasonal dynamics of earthworm activity in various ecosystems of the foothills of the Trans Ili-Alatau.

Methodology

The work is based on the results of material processing, collected by the authors in the foothills of the Trans Ili-Alatau, for the period from 2018 to 2021. The material on the species composition of earthworms and the amount is presented in connection with their distribution by types of ecosystems and soils of the Trans Ili-Alatau.

Comparison of data on the distribution of soil mesofauna, among which the most represented group is lumbricides, in different seasons allows to study seasonal fluctuations in the number of this group.

The research was carried out at the Department of biology of the Abai Kazakh national pedagogical university.

The accounting of soil mesofauna was carried out by the hand sampling method recommended by M.S. Gilyarov (1965), which is generally accepted in soil and zoological studies [11]. Soil invertebrates were taken into account when taking 0.25 sq.m. samples to the depth of soil invertebrates. However, the study found that most pedomesobionts occur within the first 40 cm of the soil profile. 12 samples were taken at each of the ten test sites. Mesofauna was taken into account by hand mining of samples in the field in layers (bedding, 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm) [12, 13].

Earthworms were fixed with a weak (0.5%) formalin solution. All material was marked where the date of excavation, the names of the area, the characteristics of the site, the sample number in the numerator and the layer in the denominator were noted, after which a desk determination of group affiliation was carried out. Identification of lumbricides was carried out in accordance with the determination tables by T.S. Vsevolodova-Perel (1979) and V.G. Matveeva (1982) [14].

During the study, a number of indicators were taken into account at the population level: species composition, species abundance, density - the number of individuals per unit area, biomass of lumbricides of the studied biogeocenoses, as well as the occurrence and number of various groups of pedobionts. Data on quantitative accounting of lumbricofauna were processed by methods of variation statistics (Quantitative methods..., 1987) [13]. For each type, the arithmetic mean is calculated. The basis for faunal analysis was the principles for studying the structure of the animal population, developed by Yu.I. Chernov (1975) [15].

Lumbricide biomass was determined by direct weighing of organisms. However, in the case of lumbricides, the weight of the contents of the stomach and intestines must be taken into account while weighing. So, the mass of the intestine of earthworms reaches 26-41% of the total body weight (Geltzer, 1979) [16].

Lumbricides were accounted for in suburban and urban ecosystems. Urban ecosystems were chosen for the reason that it is more exposed to man-made factors. Background biocenoses act as a control object. Soil samples from 8 sites of Almaty City and the Almaty region were obtained and studied as follows: 3 background sites on the northern slopes of Ili Alatau and 5 experimental sites located in different parts of the city (Figure 1).

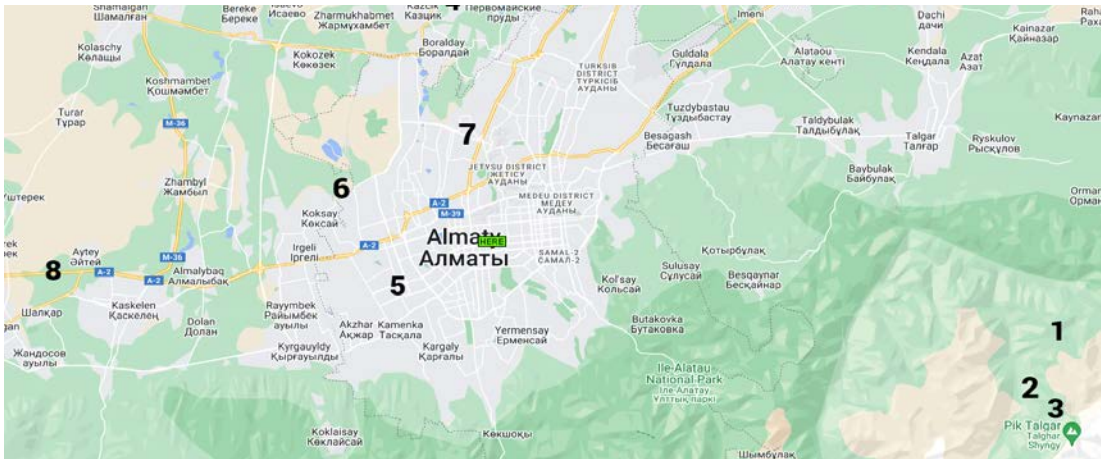

Figure 1. Location of the studied ecosystems

Note: Suburban (background) biocenoses – northern slopes of Ili Alatau: 1 – spruce forest; 2 – mixed forest; 3 – alpine meadows; Urban biocenoses – soils near petroleum storage depots, petrol stations and thermal power plants: 4 – soils near oil depots; 5 – soils near petrol stations located in different parts of the city; 6 – soils near thermal power plants; 7 – soils along city busy highways; 8 – soils along national highways.

Discussion

In the studied ecosystems of Almaty and the foothills of the Trans Ili-Alatau, we have identified representatives of the class Oligochaeta – the Lumbricidae family. Their species composition and density are shown in Table 1.

Table 1

Species composition and average abundance of soil mesofauna in suburban and urban ecosystems of Trans Ili-Alatau foothills (ex/m2)

Types of Lumbricides	Suburban biocenoses			Urban biocenoses				
	1	2	3	4	5	6	7	8
Lumbriscus rubellus (Hoffinister, 1843)	1,31	1,24	3,54	0,57	0,68	0,47	0,78	+
Aporrectodea rosea (Savigni, 1826)	0,89	0,84	1,7	0,36	0,57	0,26	0,62	+
Lumbricus terrestris (Linnaeus, 1758)	-	0,72	3,12	0,66	+	0,32	1,5	-
Eisenia fetida (Savigni, 1826)	0,62	-	1,32	0,45	0,92	-	0,72	-
Eisenia nordenskioldi (Eisen, 1879)	0,24	0,11	-	-	-	+	-	-
Octolasion lacteum (Orley, 1885)	-	0,84	+	-	-	-	1,1	0,7
Nicodrilus caliginosus (Eisen, 1874)	1,56	1,2	+	0,13	1,02	+	+	+
Aporrectodea caliginosa (Savigni, 1826)			2,02	0,91	1,14	0,74	0,5	

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Note: Suburban (background) biocenoses - northern slopes of Ili Alatau: 1-spruce forest; 2-mixed forest; 3-alpine meadows; Urban biocenoses - soils near petroleum storage depots, petrol stations and thermal power plants: 4-soils near oil depots; 5-soils near petrol stations located in different parts of the city; 6-soils near thermal power plants; 7-soils along city busy highways; 8-soils along national highways. «+» - single instances.

Earthworms (Lumbricidae) are found in all places, in both urban and suburban biocenoses. To the present, we have registered 11 species of lumbricides in the studied soils of the region. 6 species out of them are *Aporrectodea rosea* (Savigni, 1826), *Lumbricus rubellus* (Hoffmeister, 1843), *Lumbricus castaneus* (Savigni, 1826), *Octolasion lacteum* (Orley, 1885), *Dendrobaena octaedra* (Savigni, 1826) and *Aporrectodea caliginosa* (Savigni, 1826). They are widespread and ecologically plastic species that are common in forest pricing subzones of the Trans Ili-Alatau mixed forests. The largest number of Lumbricidae species noted for the fauna of the Almaty region belong to the genus Lumbricus. Species of this genus make up almost 30% of the lumbricidofauna of biogeocenosis: *Lumbricus rubellus, Lumbricus castaneus* and *Lumbricus terrestris.* The most widespread species is *Lumbricus rubellus* Hoffmeister, 1843 - a small red worm. This species can reach a length of up to 50-150 mm, a width of 4-6 mm. Pigmentation on the dorsal side is purple, the anterior end of the body is especially highly pigmented, and the tail end is flattened (Vsevolodova-Perel, 1997) [17].

Lumbricus rubellus is a bedding species that prefers moist, humus-rich soil. This species was recorded by us in all studied biogeocenoses. The distribution of this species is associated with broad-leaved species. Thus, in birch and mixed forests, the share of *L. rubellus* ranged up to 30%. However, the small red worm has also been observed in agrocenoses of both suburban and urban biocenoses, where the species accounted for up to 25%. This is due to the relatively high humus content in the soils of these biogeocenoses [18]. According to the results of chemical analysis of the soil, it was revealed that the mass fraction of organic matter in these biocenoses ranged up to 7% (Figure 2).

A *B*

Figure 2. Appearance of earthworms: a - Lumbricus rubellus, b - Aporrectodea rosea

The largest representative of lumbricides is *Lumbricus terrestris* Linnaeus, 1758, which reaches a length of 90-300 mm and a width of 6-9 mm. The pigmentation is violet to girdle, lighter posteriorly with a dark middle stripe [19].

Lumbricus terrestris, or the great red worm, lives in deeper layers of soil, being an animal which lives in a burrow [20]. This species also prefers humus-rich soils [21]. *L. terrestris* was not registered by us in the birch forest and in the agrocenosis of the Karasai region. The chemical analysis of the soil makes it possible to make the following assumption: the absence of this species in these biotopes may be due to the fact that their soils have a relatively low humus content – 3.5% and humidity – up to 12% [22].

Octolasion lacteum Orley, genus Octolasion, which reaches a length of 30-180 mm and a thickness of 2-8 mm. This species has practically no pigment, although light gray specimens with a bluish tint are most often found. Feeding only on soil humus, the upper-tier cosmopolyte *O. lacteum* is able to live in waterlogged soils and withstand a long period of oxygen deficiency [23]. So, in Trans Ili-Alatau, this species was recorded in a mixed forest, where soil moisture during the study period was 25%. *O. lacteum* accounted for 17% of the number of lumbricides found in this biocenosis.

Results

In natural biogeocenoses (sites 1-3), the dominant groups are earthworms (Lumbricidae), which account for up to 75%. Subdominant larvae and adult insects (Insecta) make up 30%, millipedes (Miriapoda) up to 24%, enhitraids (Enchytraedae) – 23%, (of the total abundance of pedobionts).

In man-made territories (areas 4-8), earthworms of the Lumbricidae family accounted for up to 70%, larvae and adults of insects 23%, millipedes 20%, enhitreids 10%. In weak biocenoses located in the vicinity of the city of Almaty (plots 4, 5, 6), earthworms make up 64% of the total number of pedobionts, millipedes make up 29%, insects – 21% and enhitreids 8.5%.

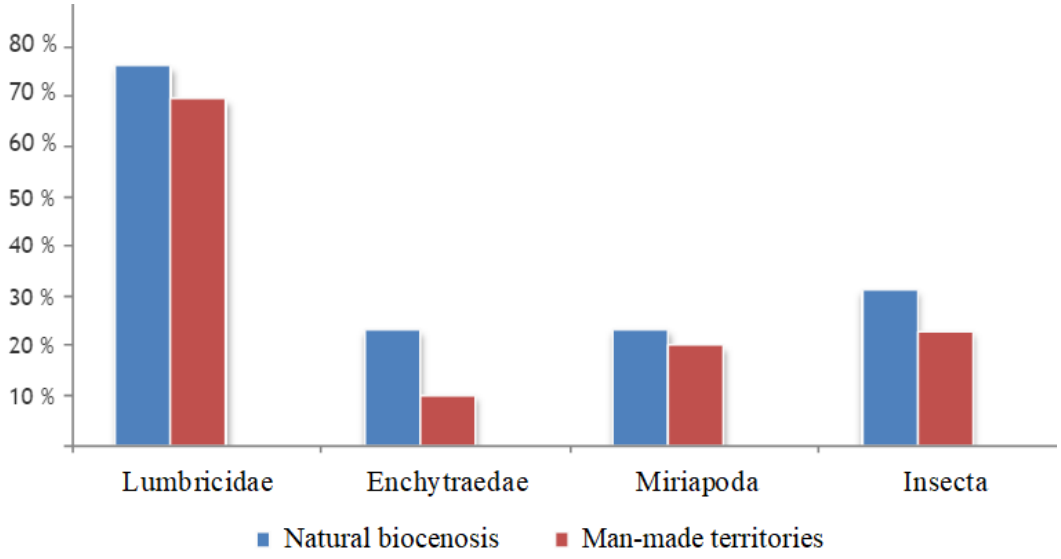

Figure 3. Occurrence of the main groups of soil mesofauna in urban and suburban biogeocenoses

Following Figure 3, you can notice a significant difference in soil mesofauna in natural and man-made biogeocenoses. But in two ecosystems, the absolute dominants are lumbricides. Earthworms, as one of the most numerous groups among other representatives of soil invertebrates, can act as an indicator of soil conditions such as humus content and soil moisture content.

Features of seasonal earthworm migrations in various biogeocenoses have been identified. The study found that in the soils of mixed forest, the seasonal fluctuations of this group of pedobionts are more smoothed than in birch or agrocenosis. However, even here, with a long absence of rain, worms left for deeper layers of soils. The change in the number of lumbricides during different periods of the growing season in birch and mixed forest is presented in Figure 4.

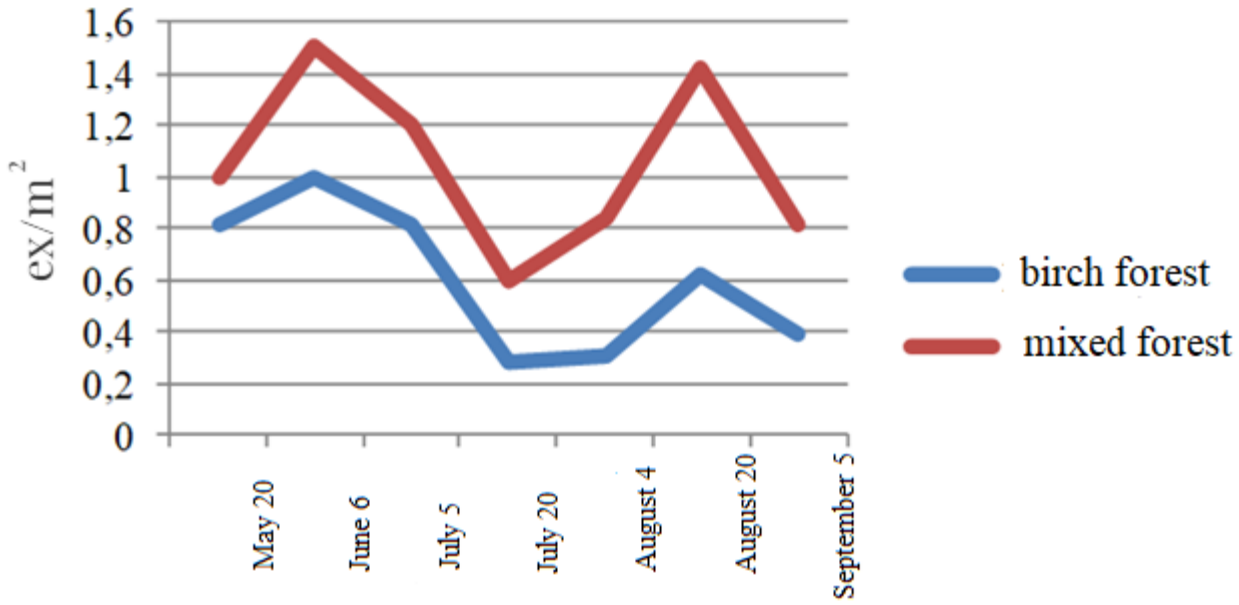

Figure 4. Seasonal ratio of the amount of soil mesofauna

The level of pedobionts activity is not regulated by the amount of litter but depends on the hydrothermal conditions of the environment, which determine, on the one hand, the level of metabolic activity and the growth rate of soil invertebrates, and on the other, the availability of the substrate. The main factors affecting the decay rate of plant litter are humidity and temperature characterized by high dynamics on the surface and relative stability in the depths of the soils [24].

Each type of soil mesofauna inhabits soils with certain amplitudes of regime fluctuations. Depending on the soil-ecological environmental conditions and the degree of anthropogenic impact, the ratio of the main trophic groups also changes. In the case of a restorative effect, the amount of organic matter decreases, the proportion of litter inhabitants and upper soil horizons in the species structure decreases.

Conclusion

As a result of soil-zoological studies, it was possible to establish the connection of the distribution of earthworms with soil-ecological conditions. The ecological and faunal characteristics of soil oligochaetes of the Lumbricidae family are presented. *A. rosea, L. rubellus, O. lacteum* are the most common. The species composition of lumbricides varies in different biotopes. In natural biogeocenoses, the number of earthworms is greater than in man-made areas. This is due to the physicochemical parameters of soils and environmental characteristics of a certain species.

While studying the seasonal dynamics of soil mesofauna, it was established that the change in the number of individual species of all identified mesofauna groups is associated with seasonal fluctuations in hydrothermal conditions and the dynamics of the arrival and decomposition of organic matter in soil ecosystems.

Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contribution

B.K. Esimov, H. Koc, G. Seribekkyzy conceived and planned the experiments. B.K. Esimov, G. Seribekkyzy, R.U. Saimova and K.I. Batyrova carried out the experiments. A.M. Aitpan and G. Seribekkyzy contributed to sample preparation. G. Seribekkyzy took the lead in writing the manuscript. All authors discussed the results and contributed to the final manuscript.

References

1. Ручин А.Б. Экология популяций и сообществ. – Москва: Академия, 2006. – 277 с.

2. Куровский А.В., Бабенко А.С. Биогеохимическая роль дождевых червей в почвенных экосистемах. Краткая история исследований и современные представления // Вестник Евразийского национального университета им. Л.Н. Гумилева. Серия: Биологические науки. – 2022. – №3(140). – С. 116-129.

3. Jouquet P., Dauber J., Lagerlof J., Lavelle P., Lepage M. Soil invertebrates as ecosystem engineers: Intended and accidental effects on soil and feedback loops // Applied Soil Ecology. – 2006. – Vol. 32(2). – P. 153-164.

4. Mazur-Paczka A., Paczka G., Kostecka J. Community structure of Lumbricidae in beech woodland of the Bieszczady National Park, Southeast Poland // Pedosphere. – 2021. – Vol. 31(3). – P. 391-397. DOI: https://doi.org/10.1016/S1002-0160(20)60090-X.

5. Amosse J., Dozsa-Farkas K., Boros G., et al. Patterns of earthworm, enchytraeid and nematode diversity and community structure in urban soils of different ages // European journal of soil biology. – 2016. – Vol. 73. – P. 46-58.

6. Kokhia M., Lortkipanidze M., Gorgadze O., et al. Earthworms (Oligochaeta: Lumbricidae) and heavy metals: content and bioaccumulation in the body // Journal of Agricultural Science. – 2022. – Vol. 33. – P. 95-100. DOI: https://10.15159/jas.22.20.

7. Ikeda H., Callaham M.A., Shefferson R.P., et al. A comparison of latitudinal species diversity patterns between riverine and terrestrial earthworms from the North American temperate zone // Journal of Biogeography. – 2020. – Vol. 47. – P. 1373-1382.

8. Безкоровайная И.Н. Биологическая диагностика и индикация почв. – Красноярск: Красноярский государственный аграрный университет, 2001. – 40 с.

9. Соколов А.А. Значение дождевых червей в почвообразовании. – Алма-Ата: АН КазССР, 1956. – 263 с.

10. Новак А.И. Биотопическое распределение дождевых червей семейства Lumbricidae в Алма-Атинской области // Вестник Ульяновской государственной сельскохозяйственной академии. – 2015. – № 4(32). – С. 78-83.

11. Гиляров М.С. Роль почвенных животных в разложении растительных остатков и круговороте веществ // Итоги науки и техники. Зоология беспозвоночных. – 1978. – Т. 5. – С. 69-71.

12. Соколова Т.Л. Диагностические возможности почвенной мезофауны // Вестник Костромского государственного университета им. Н.А. Некрасова. – 2010. – Т. 3. – С. 13-14.

13. Гиляров М.С. Зоологический метод почвенной диагностики. – Москва: Наука. – 1985. – 277 с.

14. Стриганова Б.Р. Методы фиксации, хранения и лабораторного содержания почвенных беспозвоночных // Количественные методы в почвенной зоологии. – 1978. – Т.5. – С. 72-88.

15. Чернов Ю.И. Основные синэкологические характеристики почвенных беспозвоночных и методы их анализа / Под ред. М.С. Гилярова. – Москва: Наука, 1975. – С. 198-213.

16. Рапопорт И.Б. Дождевые черви (Oligochaeta, Lumbricidae) как компонент устойчивости агроценозов в горных районах // Материалы международной конференции: Устойчивое развитие горных территорий. – Владикавказ, 2004. – С. 501-503.

17. Сергеева Е.В. Трофическая структура почвенной мезофауны в сообществах южной тайги Западной Сибири // Научный вестник Белорусского государственного университета. Серия Естественные науки. – 2016. – №11(232). – С. 41-48.

18. Iordache M., Tudor C., Brei L. Earthworms diversity (Oligochaeta: Lumbricidae) and casting chemical composition in an urban park from Western Romania // Polish Journal of Environmental Studies. – 2021. – Vol. 30(1). – P. 645-654. DOI: https://doi.org/10.15244/pjoes/123187.

19. Klein A., Eisenhauer N., Schaefer I. Invasive lumbricid earthworms in North America – different life-histories but common dispersal? // Journal of Biogeography. – 2020. – Vol. 47(3). – P. 674-685. DOI: https:// 10.1111/jbi.13744.

20. Seribekkyzy G., Saimova R.U., Saidakhmetova A.K., et al. Heavy metal effects on earthworms in different ecosystems // Journal of animal behavior and biometeorology. – 2022. – Vol. 10(3), 2228. DOI: https://doi.org/10.31893/jabb.22028.

21. Sekulic J.M., Milenkovic S.N., Stojanovic M.M., et al. Species richness and community structure of earthworms (Oligochaeta: Lumbricidae) in natural and agricultural ecosystems // Biologia. – 2022. – Vol. 77. – P. 2115-2124. DOI: https://doi.org/10.1007/s11756-022-01077-9.

22. Misirlioglu I.M., Tsekova R., Stojanovic M. On the presence of Lumbricus terrestris Linnaeus 1758 (Oligochaeta, Lumbricidae) on the Balkan Peninsula: some aspects of ecology and distribution // Turkish Journal of Zoology. – 2016. – Vol. 40. – P. 438-444. DOI: https://doi:10.3906/zoo-1509-12.

23. Newbold L.K., Robinson A., Rasnaca I. Genetic, epigenetic and microbiome characterisation of an earthworm species (Octolasion lacteum) along a radiation exposure gradient at Chernobyl // Environmental Pollution. – 2019. – Vol. 255(1). DOI: http://dx.doi.org/10.1016/j.envpol.2019.113238.

24. Kolesnikova, A.A., Taskaeva, A.A., Lapteva, E.M., et al. Vertical distribution of collembola, lumbricidae and elateridae in alluvial soils of floodplain forests // Contemporary Problems of Ecology. – 2013. – Vol. 6. – P. 34-42. DOI: https://doi.org/10.1134/S1995425513010083.

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Табиғи биогеоценоздар мен техногендік аумақтардағы Lumbricidae түрлік құрамына экологиялық-фауналық талдау

Аңдатпа. Жауын құрттары топырақ мезофаунасының негізгі бөлігін құрайды және органикалық заттардың өзгеруінде, педосфераның қалыптасуында, экожүйелердегі зат, энергия және ақпарат ағындарын реттеуде маңызды рөл атқарады. Бұл зерттеу жұмысында Іле Алатауының тау бөктеріндегі қалалық және қала маңындағы экожүйелердегі жауын құрттарының түрлік құрамы зерттелді. Жұмыс нәтижесінде Oligochaeta класындағы Lumbricidae тұқымдасының 11 түрі анықталды. Республикамызда олардың 6 түрі: Aporrectodea rosea, Lumbricus rubellus, Lumbricus castaneus, Octolasion lacteum, Dendrobaena octaedra және Aporrectodea caliginosa кең таралған. Lumbricus тұқымдасы зерттелген аумақтардағы даралар саны бойынша ең көп таралған. Техногендік және табиғи биогеоценоздарда жауын құрттарының түрлік құрамының айтарлықтай айырмашылықтары анықталды. Бірақ, екі экожүйеде де абсолютті доминанттар люмбрицидтер болып табылады. Жауын құрттарының түрлік құрамымен қатар, маусымдық динамикасы да зерттелді, олардың максималды белсенділігі температура мен ылғалдылықтың ең қолайлы арақатынасында байқалды.

Түйін сөздер: жауын құрттары, экологиялық-фауналық талдау, түрлік құрам, маусымдық динамика, Іле Алатауы.

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Эколого-фаунистический анализ видового состава Lumbricidae естественных биогеоценозов и техногенных территорий

Аннотация. Дождевые черви составляют основную часть почвенной мезофауны и играют важную роль в трансформации органического вещества, формировании педосферы, регулировании потоков вещества, энергии и информации в экосистемах. В данном

исследовании мы изучили видовой состав дождевых червей в городских и пригородных экосистемах предгорий Заилийского Алатау. В результате работы было обнаружено 11 видов семейства Lumbricidae класса Oligochaeta. Из них 6 видов: Aporrectodea rosea, Lumbricus rubellus, Lumbricus castaneus, Octolasion lacteum, Dendrobaena octaedra и Aporrectodea caliginosa являются широко распространенными в нашей республике. Род Lumbricus является наиболее распространенным по количеству особей в исследованных территориях. Установлены значительные отличия видового состава дождевых червей в техногенных и естественных биогеоценозах. Но и в двух экосистемах абсолютными доминантами являются люмбрициды. Наряду с видовым составом дождевых червей изучалась и сезонная динамика, было установлено, что их максимальная активность наблюдается при наиболее благоприятном соотношении температуры и влажности.

Ключевые слова: дождевые черви, эколого-фаунистический анализ, видовой состав, сезонная динамика, Заилийский Алатау.

References

1. Ruchin A.B. Ekologiya populyacij i soobshchestv [Ecology of populations and communities] (Moskva, Akademiya [Moscow, Academy], 2006, 277 p.). [in Russian]

2. Kurovskij A.V., Babenko A.S. Biogeohimicheskaya rol' dozhdevyh chervej v pochvennyh ekosistemah. Kratkaya istoriya issledovanij i sovremennye predstavleniya [The biogeochemical role of earthworms in soil ecosystems. A brief history of research and current views], Vestnik Evrazijskogo nacional'nogo universiteta imeni L.N. Gumileva. Seriya Biologicheskie nauki [Bulletin of the Eurasian national university named after L.N. Gumilev. Biological sciences series], 3 (140), 116-129 (2022). [in Russian]

3. Jouquet P., Dauber J., Lagerlof J., Lavelle P., Lepage M. Soil invertebrates as ecosystem engineers: Intended and accidental effects on soil and feedback loops, Applied Soil Ecology, 32 (2), 153-164 (2006).

4. Mazur-Paczka A., Paczka G., Kostecka J. Community structure of Lumbricidae in beech woodland of the Bieszczady National Park, Southeast Poland, Pedosphere, 31(3), 391-397 (2021). DOI: https://doi.org/10.1016/S1002-0160(20)60090-X.

5. Amosse J., Dozsa-Farkas K., Boros G., et al. Patterns of earthworm, enchytraeid and nematode diversity and community structure in urban soils of different ages, European journal of soil biology, 73, 46-58 (2016).

6. Kokhia M., Lortkipanidze M., Gorgadze O., et al. Earthworms (Oligochaeta: Lumbricidae) and heavy metals: content and bioaccumulation in the body, Journal of Agricultural Science, 33, 95-100 (2022). DOI: https://10.15159/jas.22.20.

7. Ikeda H., Callaham M.A., Shefferson R.P., et al. A comparison of latitudinal species diversity patterns between riverine and terrestrial earthworms from the North American temperate zone, Journal of Biogeography, 47, 1373-1382 (2020).

8. Bezkorovajnaya I.N. Biologicheskaya diagnostika i indikaciya pochv [Biological diagnostics and indication of soils], (Krasnoyarsk: Krasnoyarskij gosudarstvennyj agrarnyj universitet [Krasnoyarsk: Krasnoyarsk State Agrarian University], 2001, 40 p.). [in Russian]

9. Sokolov A.A. Znachenie dozhdevyh chervej v pochvoobrazovanii [Importance of earthworms in soil formation] (Alma-Ata: AN KazSSR [Alma-Ata: Academy of sciences of the Kazakh SSR], 1956, 263 p.). [in Russian]

10. Novak A.I. Biotopicheskoe raspredelenie dozhdevyh chervej semejstva Lumbricidae v Alma-Atinskoj oblasti [Biotopic distribution of earthworms of the family Lumbricidae in the Alma-Ata region], Vestnik Ul'yanovskoj gosudarstvennoj sel'skohozyajstvennoj akademii [Bulletin of the Ulyanovsk state agricultural academy], 4(32), 78-83 (2015). [in Russian]

11. Gilyarov M.S. Rol' pochvennyh zhivotnyh v razlozhenii rastitel'nyh ostatkov i krugovorote veshchestv [The role of soil animals in the decomposition of plant residues and the circulation of substances], Itogi nauki i tekhniki. Zoologiya bespozvonochnyh [The results of science and technology. Zoology of invertebrates], 5, P. 69-71 (1978) [in Russian]

12. Sokolova T.L. Diagnosticheskie vozmozhnosti pochvennoj mezofauny [Diagnostic capabilities of the soil mesofauna], Vestnik Kostromskogo gosudarstvennogo universiteta im. N.A. Nekrasova [Bulletin of the Kostroma state university named after N.A. Nekrasov], 3, 13-14 (2010). [in Russian]

13. Gilyarov M.S. Zoologicheskij metod pochvennoj diagnostiki [Zoological method of soil diagnostics] (Moskva, Nauka [Moscow: Science], 1985, 277 p.). [in Russian]

14. Striganova B.R. Metody fiksacii, hraneniya i laboratornogo soderzhaniya pochvennyh bespozvonochnyh [Methods of fixation, storage and laboratory maintenance of soil invertebrates], Kolichestvennye metody v pochvennoj zoologii [Quantitative methods in soil zoology], 72-88 (1978). [in Russian]

15. Chernov Yu.I. Osnovnye sinekologicheskie harakteristiki pochvennyh bespozvonochnyh i metody ih analiza [The main synecological characteristics of soil invertebrates and methods of their analysis], Pod red. M.S. Gilyarova [Edited by M.S. Gilyarov] (Moskva, Nauka [Moscow: Science], 1975, 198-213 p.). [in Russian]

16. Rapoport I.B. Dozhdevye chervi (Oligochaeta, Lumbricidae) kak komponent ustojchivosti agrocenozov v gornyh rajonah [Earthworms (Oligochaeta, Lumbricidae) as a component of the sustainability of agrocenoses in mountainous areas] , Materialy mezhdunarodnoj konferencii: Ustojchivoe razvitie gornyh territorij [Materials of the international conference: Sustainable development of mountain territories], Vladikavkaz, 501-503 (2004). [in Russian]

17. Sergeeva E.V. Troficheskaya struktura pochvennoj mezofauny v soobshchestvah yuzhnoj tajgi Zapadnoj Sibiri [Trophic structure of the soil mesofauna in the communities of the southern taiga of Western Siberia], Nauchnyj vestnik Belorusskogo gosudarstvennogo universiteta. Seriya Estestvennye nauki [Scientific bulletin of the Belarusian state university. Natural sciences series], 11(232), 41-48 (2016). [in Russian]

18. Iordache M., Tudor C., Brei L. Earthworms diversity (Oligochaeta: Lumbricidae) and casting chemical composition in an urban park from Western Romania, Polish Journal of Environmental Studies, 30(1), 645-654 (2021). DOI: https://doi.org/10.15244/pjoes/123187.

19. Klein A., Eisenhauer N., Schaefer I. Invasive lumbricid earthworms in North America – different life-histories but common dispersal? Journal of Biogeography, 47(3), 674-685 (2020). DOI: https:// 10.1111/jbi.13744.

20. Seribekkyzy G., Saimova R.U., Saidakhmetova A.K., et al. Heavy metal effects on earthworms in different ecosystems, Journal of animal behavior and biometeorology, 10 (3), 2228 (2022). DOI: https://doi.org/10.31893/jabb.22028.

21. Sekulic J.M., Milenkovic S.N., Stojanovic M.M., et al. Species richness and community structure of earthworms (Oligochaeta: Lumbricidae) in natural and agricultural ecosystems, Biologia, 77, 2115-2124 (2022). DOI: https://doi.org/10.1007/s11756-022-01077-9.

22. Misirlioglu I.M., Tsekova R., Stojanovic M. On the presence of Lumbricus terrestris Linnaeus 1758 (Oligochaeta, Lumbricidae) on the Balkan Peninsula: some aspects of ecology and distribution, Turkish Journal of Zoology, 40, 438-444 (2016). DOI: https://doi:10.3906/zoo-1509-12.

23. Newbold L.K., Robinson A., Rasnaca I. Genetic, epigenetic and microbiome characterisation of an earthworm species (Octolasion lacteum) along a radiation exposure gradient at Chernobyl, Environmental Pollution, 255(1) (2019). DOI: http://dx.doi.org/10.1016/j.envpol.2019.113238.

24. Kolesnikova, A.A., Taskaeva, A.A., Lapteva, E.M., et al. Vertical distribution of collembola, lumbricidae and elateridae in alluvial soils of floodplain forests, Contemporary Problems of Ecology, 6, 34-42 (2013). DOI: https://doi.org/10.1134/S1995425513010083.

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