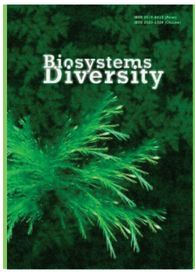

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Diversity and features of the fauna of herpetobiont beetles (Carabidae, Tenebrionidae, Elateridae, Scarabaeidae) of the Lower Zeravshan, Uzbekistan

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The Lower Zeravshan district of Uzbekistan is characterized by the most arid climate and is particularly affected by global warming and anthropogenic pressure. The biodiversity of herpetobiont beetles in this region has not been sufficiently studied, and this makes it difficult to monitor the fauna of the region. This work was carried out to assess the biodiversity and ecological features of some groups of herpetobiont beetles during 2019–2023. Soil and light traps, soil excavations and manual collection were used to collect material. A total of 131 species of beetles were identified. The carabid fauna of the region is represented by 43 species belonging to nine subfamilies, 19 tribes, and 28 genera. For the fauna of the Republic, two species were recorded for the first time (*Syntomus obscuroguttatus* (Duftschmid, 1812) and *Scarites subcylindricus* Chaudoir, 1843). The darkling beetle fauna includes 46 species belonging to three subfamilies, 16 tribes, and 30 genera. For the first time, five species were recorded for the fauna of the Republic of Uzbekistan (*Cyphogenia lucifuga* Adams, 1817, *Trigonoscelis apicalis* Reitter, 1907, *Colpotus sulcatus* (Menetries, 1838), *Tribolium destructor* Uyttenboogart, 1933, *Pentaphyllus chrysomeloides* (Rossi, 1792)). The fauna of ground beetles and darkling beetles of the Lower Zeravshan consists of two species complexes that differ sharply from each other – xerophilic (inhabiting desert biocenoses) and hygromesophilic (inhabiting agricultural landscapes). The similarity coefficients of the fauna of these two types of biocenoses are very low. The fauna of click beetles is represented by 10 species belonging to four subfamilies and seven genera. The fauna of lamellar beetles consists of 31 species (32 with subspecies), belonging to eight subfamilies, 13 tribes, and 19 genera. In agrocenoses, a significant increase in the number of herpetobionts is observed in the first days of June. But their maximum number is observed in early July. It has been established that seasonal fluctuations in the number of representatives of the families Carabidae, Elateridae, Staphylinidae, and Tenebrionidae occur almost in parallel. Fluctuations in the number of representatives of the Scarabaeidae family do not correspond to the above pattern, and the maximum value is observed at the end of July. The data obtained can be used to assess biodiversity and environmental monitoring of arid zones of Uzbekistan.

Keywords: herpetobiont beetles; biodiversity; degree of dominance; diversity index; similarity coefficient; desert; agrocenoses.

Introduction

Beetles or Coleoptera, being the most diverse and biologically advanced group of insects, constitute more than a third (392,415 species) of all known insects (Zhang, 2013; Bouchard et al., 2017). Characterized by high ecological diversity and species composition, herpetobiont beetles participate in the migration of nutrients created by plants in the soil. They are an important and integral part of trophic relationships. If some of them, being predators, play a huge role in reducing the number of harmful insects and weeds (Guseva & Koval, 2013; Halimov, 2020), then the other part, being pests of agricultural plants, have a high economic significance (Zenner de Polanía, 2014; Poggi, 2021; Açıkgöz, 2022).

Monitoring the health of ecosystems and changes in habitat biodiversity depends on a thorough knowledge of the existing flora and fauna of the region. An important step in achieving such knowledge is a comprehensive assessment of the biodiversity of specific taxa in target areas, especially poorly studied ones. In addition to increasing general knowledge of biodiversity in a given region, such data can serve as a basis for quantifying the impacts of biotic and abiotic disturbances and their interactions in future studies (Schowalter, 2012). The Lower Zeravshan geographical district of Uzbekistan, which mainly includes the plains of the Bukhara region, is characterized by the most arid climate. The main part of the territory is desert. The water resources of the region are very limited, the average annual precipitation does not exceed 95–125 mm, and the air temperature in summer reaches up to 45–48 °C, which leads to the formation of unique fauna and flora (Hasanov et al., 2010). Climate acts as a regional filter that directs the distribution of species according to their tolerance to environmental conditions and resource requirements. In particular, temperature and precipitation have a strong influence on both diversity and abundance structure (Hortal et al., 2011). Precipitation patterns are generally the most important driver of functional diversity at the regional scale (Wen et al., 2019).

Research on the fauna of invertebrate animals was carried out mainly in the upper and middle parts of the Zeravshan Valley, the main biotopes of which are mountainous and foothills. In recent years, intensive research has been carried out on the biodiversity of beetles (Zokirova & Khalimov, 2022; Khalimov, 2023; Khalimov et al., 2023; Romantsov & Rakhimov, 2023).

The Lower Zeravshan differs significantly in climatic conditions from the upper and middle parts of the Zeravshan Valley. The biodiversity of vegetation cover and its features of the Lower Zeravshan region has been well studied and it includes mainly xerohalophytic plants (Akhmedov et al., 2021; Bazarov et al., 2023). However, information about the fauna of invertebrate animals, especially beetles, is extremely insufficient. Some information on individual groups of herpetobionts in the region is found only in a few works (Alimjanov & Bronshteyn, 1956; Davletshina, 1967; Davletshina et al., 1979; Egorov & Rakhimov, 2015). However, in recent years, species of beetles new to science have been discovered in museum exhibits related to this region (Nabozhenko, 2006; Chigray & Nabozhenko, 2018; Chigray & Ivanov, 2020).

The purpose of this study was to obtain initial data on the distribution of herpetobiont beetles of the families Carabidae, Tenebrionidae, Elateridae and Scarabaeidae in the Lower Zeravshan geographical district of Uzbekistan. However, there is currently no checklist of any of these taxa for the area, making it difficult to assess species distributions. In this study, we list 131 beetle species from four families collected in this region from 2019 to 2023 and discuss their taxonomic composition and seasonal dynamics.

Material and methods

The studies were carried out during the period 2019-2023 in the territories of Bukhara, partially Navinsky, and Kashkadarya regions of Uzbekistan (Fig. 1). The objects of research were representatives of four families of beetles (Carabidae, Tenebrionidae, Elateridae, Scarabaeidae). When determining the population dynamics of herpetobionts, representatives of the family Staphylinidae were also counted, but identification of these beetles to the species level was not carried out. To collect beetles, soil traps of the Barber–Heydemann type (Barber, 1931; Heydemann, 1955), light traps, soil excavations, and manual collection (night and day) were used. The size of the soil excavations is 50 x 50 x 50 cm. The collection of material in deserted areas was carried out during short-term expeditions (3–5 days). The frequency of expeditions was twice a month. Constant observations of the population dynamics of herpetobionts were carried out in agricultural landscapes. The species of the collected beetles, were identified, their number was counted, and a collection was compiled. In total, during the research, more than 9,000 samples of herpetobiont beetles were collected and processed.

The degree of dominance was determined according to the Renkonen scale (Renkonen, 1944), where more than 5% are dominant species, from 2% to 5% are subdominant species, 1–2% are low-abundance species, and less than 1% are rare species.

Statistical calculations of biodiversity were carried out according to the guidance of Dunaev (1997):

– Margalef index – $DMg = (S–1) / \ln N$, where S – is the number of identified species, N – is the total number of individuals of all identified species, ln – is the natural logarithm;

– Shannon's index – $H' = –\Sigma p_i \ln p_i$, where p_i – is the proportion of individuals of the i – the species;

– Menhinick index – $DMn = S/\sqrt{N}$, where S – is the total number of identified species, N – is the total number of individuals of all species;

– Shannon alignment – $E = H'/\ln S$, where H' – is the Shannon index, S – is the number of species;

– Simpson index – $D(S\lambda) = \Sigma(n_i(n_i – 1))/N(N – 1)$, where n – is the number of individuals of i species, N – is the total number of individuals;

– Berger-Parker index – $d = N_{max}/N$, where N_{max} – is the number of individuals of the most abundant species, N – is the total number of individuals of all species of the sample;

– Chekanovsky-Sørensen coefficient – $CN = 2jN/(aN + bN)$, where aN + bN – is the total number of individuals in sites A and B, jN – is the smallest of the two abundance of species found in both sites;

– Jaccard coefficient: $C_j = j/(a + b – j)$, where j – is the number of common species in both territories (sites, samples), a and b – is the number of species in each territory (sites, samples).

The compiled collection of beetles is stored in the Entomological Collection of Samarkand University.

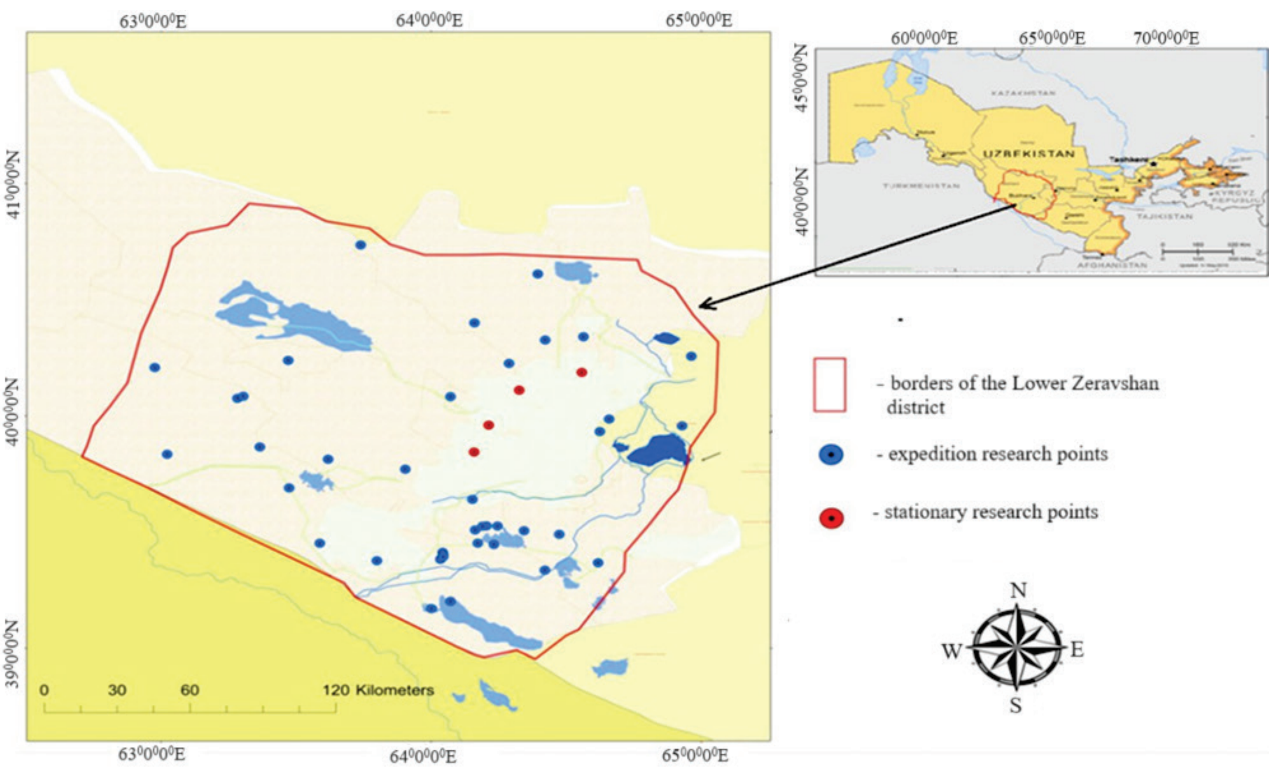

Fig. 1. Research area map (places of collection of material)

Results

As a result of the research, 131 species of beetles belonging to the four families studied were identified (Table 1).

Carabidae. The carabid fauna of the study area is represented by 43 species belonging to 9 subfamilies, 19 tribes, and 28 genera. For the first time, two species were recorded for the fauna of the Republic (*Syntomus obscuroguttatus* and *Scarites subcylindricus*). The discovered ground beetles belong to nine subfamilies, and in terms of species diversity, the subfamily Harpalinae Bonelli, 1810 has clear superiority. Representatives of this subfamily consist of 21 species, accounting for 49% of all species. The dominance of the subfamily Harpalinae increases more clearly when comparing the abundance of individuals. Among all collected beetles, 82% were individuals of the subfamily Harpalinae. The share of the subfamily Trechinae in species diversity was 19.8%, but in terms of the abundance of individuals, the share of this subfamily is only 3.6%. Subfamilies in the ground beetle fauna with only one species recorded in the region are Carabinae, Brachininae, Melaeninae and Broscinae.

Table 1
Taxonomic composition of herpetobiont beetles of Lower Zeravshan

Family	Subfamily	Tribe	Species
Carabidae	Cicindelinae	Megacephalini	*Megacephala euphratica* Dejean, 1822
		Cicindelini	*Cicindela turkestanica turkestanica* Ballion, 1876
			Cylindera sublacerata (Solskiy, 1874)
	Omophroninae	Omophronini	*Omophron limbatum* (Fabricius, 1777)
			O. rotundatum Chaudoir, 1852
	Carabinae	Carabini	*Calosoma auropunctatum dsungaricum* Gilber, 1833
	Brachininae	Brachinini	*Brachinus explodens* Duftschmid, 1812
	Scaritinae	Scaritini	*Scarites terricola* Bonelli, 1813
			S. bucida Pallas, 1776
			S. subcylindricus Chaudoir, 1843
			S. procerus eurytus Fischer von Waldheim, 1828
		Dyschiriini	*Dyschirius cylindricus* (Dejean, 1825)
	Melaeninae	Cymbionotini	*Cymbionotum semelederi* (Chaudoir, 1861)
	Broscinae	Broscini	*Broscus asiaticus* Ballion, 1871
	Trechinae	Bembidiini	*Bembidion almum* J.Sahlberg, 1900
			B. luridicorne Solsky, 1874
			B. quadrimaculatum Linnaeus, 1761
			Elaphropus sp.
		Tachyini	*Tachys centriustatus* Reitter, 1894
			T. sp.
		Trechini	*Trechus quadristriatus* Schrank,1781
		Pogonini	*Sirdenus grayii* (Wollaston, 1862)
	Harpalinae	Chlaeniini	*Chlaenius festivus* Panzer, 1796
			C. inderiensis Motschulsky, 1849
		Harpalini	*Acupalpus flaviceps* (Motschulsky, 1850)
			Harpalus affinis (Schrank, 1781)
			H. distinguendus Duftschmid, 1812
			H. griseus Panzer, 1796
			H. rubripes Duftschmid, 1812
			H. rufipes De Geer, 1774
			Loxoncus procerus (Schaum, 1858)
			Liochirus cycloderus (Solsky, 1874)
			Machozetus lehmanni Menetries, 1848
			M. concinnus C.A. Dohrn, 1885
		Lebiini	*Cymindis andreae* Ménétriés, 1832
			Syntomus obscuroguttatus (Duftschmid, 1812)
			Singilis flavipes (Solskiy, 1874)
			Lebia festiva Faldermann, 1836
		Pterostichini	*Poecilus cupreus* Linnaeus,1758
		Sphodrini	*Calathus ambiguus* Paykull, 1790
		Zabrini	*Amara aenea* De Geer,1774
			A. ovata Fabricius, 1792
			A. similata Gyllenhal,1810
Tenebrionidae	Pimeliinae	Adesmiini	*Adesmia planidorsis* Reitter, 1916
		Akidini	*Cyphogenia gibba* Fischer von Waldheim, 1820
			C. limbata Fischer von Waldheim, 1821
			C. lucifuga Adams, 1817
		Erodiini	*Diaphanidus ferrugineus*(Fischer von Waldheim, 1821)
		Epitragini	*Sphenaria menetriesi* Semenov, 1891
		Pimeliini	*Diesia sexdentata* Fischer von Waldheim, 1821
			Earophanta tomentosa (Semenov, 1893)
			Lasiostola grandis Kraats,1883
			L. hirta Medvedev, 1964
			Ocnera pilicollis Faldermann, 1836
			Pisterotarsa gigantea (Fischer von Waldheim, 1821)
			Podhomala nitida (Baudi di Selve, 1876)
			P. heydeni Reitter, 1907
			Sternodes caspicus (Pallas, 1781)
			Trigonoscelis apicalis Reitter, 1907
			T. seriata Menetries, 1849
			T. sublaevicollis Reitter, 1893
			T. sp.
		Stenosini	*Stenosis sulcicollis* Menetries,1849.
		Tentyriini	*Alcinoeta helopioides* Menetries, 1849
			Microdera sp.
			Psammocryptus bogatchevi Nabozhenko, Chigray & Bekchanov, 2022
			Tentyria gigas (Faldermann, 1836)
			T. sp.
		Zophosini	*Zophosis punctata* Brulle, 1832
			Z. rotundata Menetrie, 1849
			Z. scabriuscula Menetries, 1849
	Tenebrioninae	Blaptini	*Blaps deplanata* Ménétriés, 1832
			B. fausti Seidlitz, 1893
			B. scutellata Fischer de Waldheim G., 1844
			B. titanus Ménétriés, 1849
		Helopini	*Catomus niger* (Kraatz, 1882)
		Melanimonini	*Cheirodes brevicollis* Wollaston, 1864
		Opatrini	*Gonocephalum rusticum* (Olivier, 1811)
			G. setulosum (Faldermann, 1837)
			Opatroides punctulatus Brulle, 1832
			Scleropatrum breviusculus (Reitter, 1889)
			S. hirtulum (Baudi, 1875).
			S. seidlitzi Reitter, 1898
		Pedinini	*Colpotus sulcatus* (Menetries, 1838)
		Tenebrionini	*Hedyphanes coerulescens* Fischer de Waldheim, 1822
			Tenebrio molitor Linnaeus, 1758
			T. obscurus Fabricius, 1792
		Triboliini	*Tribolium destructor* Uyttenboogart, 1933
	Diaperinae	Diaperini	*Pentaphyllus chrysomeloides* (Rossi, 1792)
Elateridae	Elaterinae	Agriotini	*Agriotes meticulosus* Candèze, 1863
			A. caspicus Heyden, 1883
			A. oxianus Iablokoff-Khnzorian, 1970
		Ampedini	*Reitterelater fulvus* (Reitter, 1891)
	Agrypninae	Conoderini	*Drasterius atricapillus* (Germar, 1824)
			D. figuratus (Germar, 1844)
			Aeoloides grisescens (Germar, 1844)
	Melanotinae		*Melanotus acuminatus* Reitter, 1891
	Cardiophorinae	Cardiophorini	*Cardiophorus hauseri* Schwarz, 1900
			Dicronychus nigropunctatus (Motschulsky, 1860)
Scarabaeidae	Scarabaeinae	Scarabaeini	*Scarabaeus babori* Balthasar, 1934
			S. sacer Linnaeus, 1758
			S. transcaspicus Stolfa, 1938
			S. carinatus (Gebler, 1841)
		Coprini	*Copris hispanus cavolinii* (Petagna, 1792)
			C. lunaris (Linnaeus, 1758)
		Onitini	*Onitis humerosus* (Pallas, 1771)
		Onthophagini	*Onthophagus vacca* (Linnaeus, 1767)
			O. taurus (Schreber, 1759)
	Aphodiinae	Aphodiini	*Teuchestes fossor* (Linnaeus, 1758)
			Bodilus caspius (Ménétriés, 1832)
			Acrossus rufipes (Linnaeus, 1758)
			A. luridus (Fabricius, 1775)
	Geotrupinae	Lethrini	*Lethrus rosmarus* Ballion, 1871
			L. majusculus Semenov, 1899
	Dynastinae	Oryctini	*Oryctes nasicornis turcestanicus* Minck, 1914
			O. nasicornis punctipennis Motschulsky, 1860
		Pentodontini	*Pentodon bidens bidens* (Pallas, 1771)
			P. brachypterus Gusakov, 2004
	Melolonthinae	Melolonthini	*Melolontha hippocastani* Fabricius, 1801
			M. melolontha (Linnaeus, 1758)
			M. afflicta afflicta Ballion, 1871
			Polyphylla alba (Pallas, 1773)
			P. adspersa Motschulsky, 1854
		Rhizotrogini	*Amphimallon solstitiale* (Linnaeus, 1758)
			A. sogdianum Nikolajev, 2001
	Rutelinae	Anomalini	*Phyllopertha horticola* (Linnaeus, 1758)
	Cetoniinae	Cetoniini	*Cetonia aurata* (Linnaeus, 1758)
			Protaetia ungarica (Herbst, 1790)
			Oxythyrea cinctella (Schaum, 1841)
			Tropinota hirta (Poda, 1761)
	Valginae	Valgini	*Valgus hemipterus* (Linnaeus, 1758)

When analyzing the species composition of the carabid fauna by tribe, it was found that 23.3% of the detected species (10 species) were representatives of the tribe Harpalini. Next come Scaritini, Bembidiini, and Lebiini (9.3% each (four species)). However, the share of different tribes in terms of the abundance of individuals does not correspond to their share in terms of taxonomic diversity (Fig. 2). In terms of the abundance of individuals, the tribe Harpalini consolidates its leading position (42.2% of all collected beetles). This is due to the abundance of dominant *Harpalus distinguendus* and *Machozetus lehmanni*. It is followed by the tribes Schodrini, Scaritini and Zabrini. If the share of the tribe Sphodrini in terms of species diversity is 2.3%, then in terms of the abundance of individuals its share increases to 27.9%. This is due to the high population density of the dominant species *Calathus ambiguus*.

Among the species found, *Calathus ambiguus* (dominance rate 20.2%), *Machozetus lehmanni* (17.4%), *Harpalus distinguendus* (16.2%), *Scarites bucida* (7.6%) and *Machozetus concinnus* (5.4%) are dominant species. *Scarites terricola* (4.3%), *Megacephala euphratica* (4.0%), *Amara aenea* (2.9%), *A. ovata* (2.3%), and *Harpulus rubripes* (2.1%) are the subdominant species.

The main part of the territory of Lower Zeravshan is occupied by desert landscapes and agricultural landscapes, which differ sharply in their hydrothermal regime. The species composition of ground beetles in these biocenoses is close in the number of species. However, they differ sharply in the composition of fauna. In desert biocenoses, 22 species of ground beetles were identified, and in agrocoenoses, 23 species. However, there are only four species common to the two biocenoses.

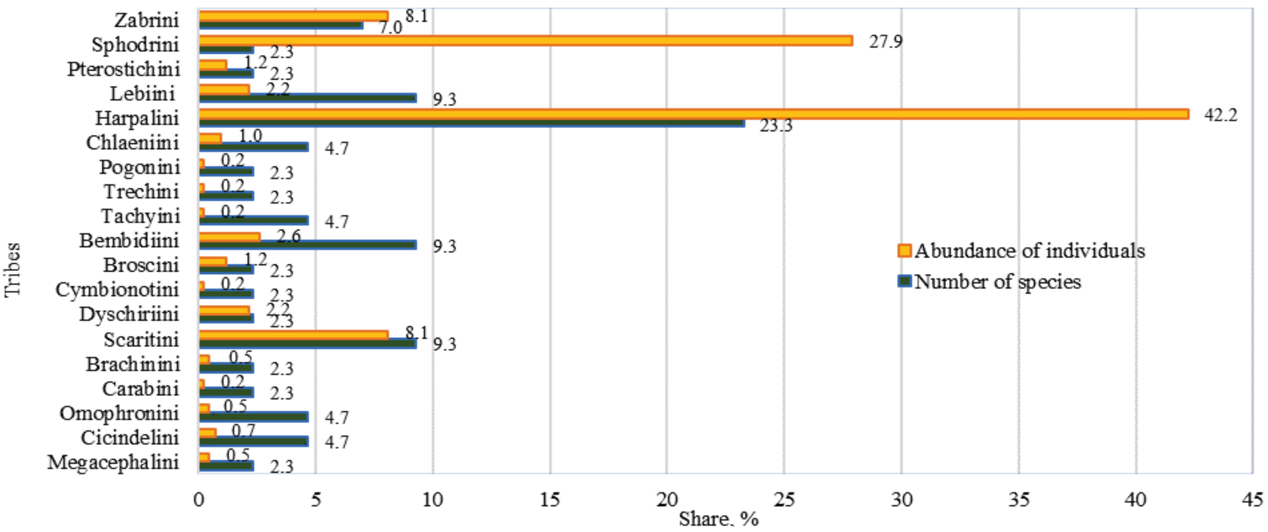

Fig. 2. Proportion of different tribes in the ground beetle fauna by number of species and number of individuals

Desert biocenoses are dominated by species of the genera *Megacephala*, *Scarites*, *Machozetus*, and *Dyschirius*, which are most adapted to the harsh conditions of deserts. In the sand dunes, *Scarites bucida* is most numerous – one of the largest representatives of ground beetles in this region. Another dominant species of this genus, *Scarites terricola*, is common in all biocenoses of the region, including agrocenoses. The only representative of the genus *Megacephala* in the Palaearctic, *M. euphratica* dominates in saline deserts. In deserts with hard soil, the most numerous are *Machozetus lehmanni* and *M. concinnus* – endemic to Central Asia.

In agrocenoses, the genera *Harpalus* (five species, 21.8%), *Bembidion*, and *Amara* (three species, 13.0% each) dominate in terms of the number of species, and the most numerous species in the genera *Calathus*, *Harpalus* and *Amara* in terms of the number of individuals. In general, in agrocenoses compared to deserts, the number of dominant species decreases, but the number of subdominant and small species increases.

The indices of ecological diversity of the fauna of agrocenoses and desert biocenoses do not differ much. However, a more uniform distribution is observed in desert biocenoses. However, the similarity coefficients show that the ground beetle fauna of these biocenoses differ very sharply (Jaccard coefficient – 0.098; Chekanovsky-Sørensen index – 0.078, Table 2).

Table 2
Comparative ecological analysis of the fauna of ground beetles and darkling beetles of agrocenoses and natural desert biocenoses

Ecological diversity indices	Ground beetles		Darkling beetles	
	agrocenoses	desert biocenoses	settlements and agrocenoses	desert biocenoses
Species richness indices				
Margalef Index:	3.87	3.75	3.17	5.40
Shannon Index:	2.09	2.06	2.29	2.51
Menhinick Index:	1.43	1.34	1.12	1.70
Shannon Alignment:	0.666	0.864	0.778	0.717
Measures of dominance				
Simpson Index:	0.216	0.196	0.123	0.133
Berger Parker Index:	0.397	0.374	0.204	0.303
Similarity factors				
Jaccard coefficient:	0.098		0.057	
Chekanovsky–Sørensen coefficient:	0.078		0.130	

Thus, the fauna of ground beetles of the Lower Zeravshan consists of two species complexes – xerophilic (inhabiting desert biocenoses) and hygromesophilic (inhabiting agricultural landscapes).

Tenebrionidae. The darkling beetle fauna of the studied region includes 46 species belonging to three subfamilies, 16 tribes, and 30 genera (Table 1). Among the discovered species, five species (*Cyphogenia lucifuga*, *Trigonoscelis apicalis*, *Colpotus sulcatus*, *Tribolium destructor*, and *Pentaphyllus chrysomeloides*) were noted for the first time for the fauna of the Republic of Uzbekistan. The main part of the identified species belongs to the subfamily Pimeliinae (28 species, 61.0%). Moreover, in terms of the abundance of individuals, representatives of Pimeliinae make up 67.8% of all collected darkling beetles. The subfamily Tenebrioninae is represented by 17 species (37%), and the subfamily Diaperinae is represented by a single species (2%).

In the fauna of darkling beetles, the proportion of different tribes in their species diversity does not correspond to their quantitative indicators. For example, the tribe Opatrini, whose share in species diversity is only 13.0%, is 21.3% of all beetles in terms of the abundance of individuals. And vice versa, if in terms of the number of individual representatives of the tribe, Pimeliini make up 15%, then the share of this tribe in species diversity is 28%. The tribe Adesmiini, which has only one species in this region and whose share in species diversity is only 2%, accounts for 17.3% of the fauna in terms of the abundance of individuals. A similar situation is also observed with respect to the share of the Stenosini tribe (increases from 2% to 9%, Fig. 3).

In the study region, *Adesmia planidorsis* (dominance rate 17.3%), *Stenosis sulcicollis* (9.0%), *Scleropatrum breviusculus* (7.6%), *Cyphogenia lucifuga* (6.2%), *Trigonoscelis apicalis* (6.1%), *Scleropatrum seidlitzi* (5.8%), *Zophosis scabriuscula* (5.8%) and *Ocnera pilicollis* (5.2%) are the dominant species. In comparison, *Tentyria gigas* (4.3%), *Scleropatrum hirtulum* (3.8%), *Cyphogenia limbata* (3.7%) and *Blaps scutellata* (3.0%) are subdominant species.

It should be noted that the six species of darkling beetles present in museum collections (*Earophanta tomentosa*, *Lasiostola hirta*, *Podhomala nitida*, *Podhomala heydeni*, *Catomus niger* and *Sternodes caspicus*) were not observed in the field. In addition, in field studies, *Trigonoscelis seriata* and *Psammocryptus bogatchevi* were found in single specimens. Apparently, the species mentioned above are very small in number, and the state of their population requires special research.

It has been established that the fauna of darkling beetles in deserts differs significantly from the fauna of agrocenoses and cultivated landscapes of populated areas.

The species diversity of darkling beetles in deserts is much higher (33 species) compared to agrocenoses and populated areas (19 species), which is also expressed in the values of the identified indices of ecological diversity (Table 2). However, the Shannon evenness index was higher in agrocenoses, which means a high degree of dominance in desert biocenoses of species adapted to extreme desert conditions. The species of darkling beetles that dominate in deserts have not been identified in agrocenoses (except for *Blaps scutellata*). If *Adesmia planidorsis*, *Cyphogenia lucifuga*, *Trigonoscelis apicalis*, *Ocnera pilicollis*, *Cyphogenia limbata* and *Blaps scutellata* dominate in desert biocenoses, then in agrocenoses and populated areas the dominant species are *Stenosis sulcicollis*, *Scleropatrum breviusculus*, *S. seidlitzi*, *S. hirtulum*, *Zophosis scabriuscula* and *Tentyria gigas*. The similarity coefficients of the fauna of these two types of biocenoses have very low indicators (Jaccard coefficient – 0.057, Chekanovsky-Sørensen coefficient – 0.130). Thus, the darkling beetle fauna of the study area consists of two distinctly different species complexes.

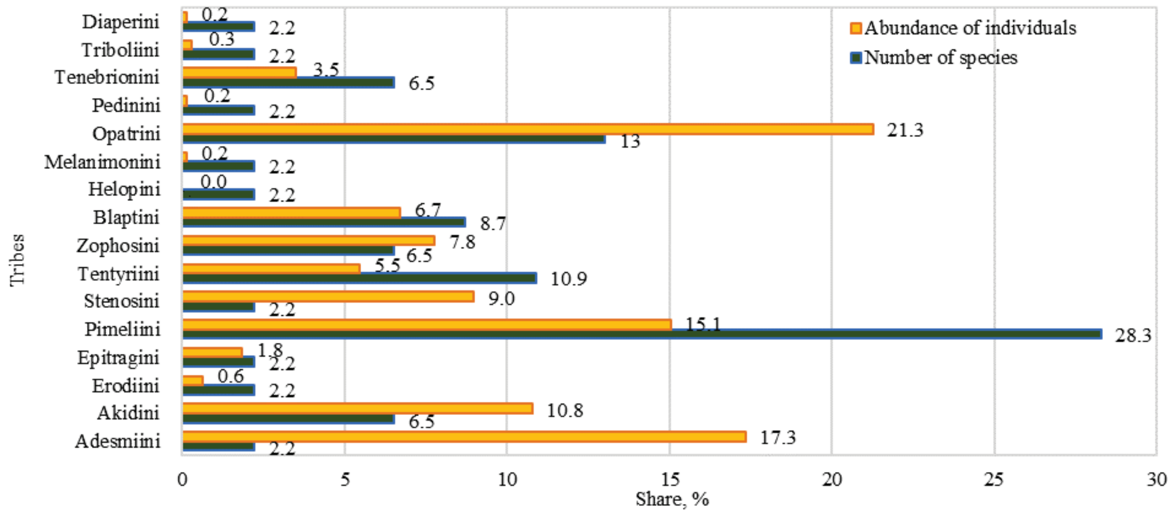

Fig. 3. Proportion of different tribes in the darkling beetle fauna by number of species and number of individuals

Elateridae. During the research, 10 species of click beetles belonging to four subfamilies and seven genera were discovered in the biocenoses of the region. Four species have been identified from the subfamily Elaterinae, three species from the subfamily Agrypninae, two species from the subfamily Cardiophorinae, and one species from the subfamily Melanotinae. If the subfamily Elaterinae is the leader in species diversity (40%), then the subfamily Agrypninae is the leader in the abundance of individuals (38%).

In the study area, the dominant species among click beetles are *Drasterius figuratus* (dominance rate 34.8%), *Melanotus acuminatus* (22.3%), *Agriotes meticulosus* (17.4%) and *Cardiophorus hauseri* (12.0%). These four species together account for 86.4% of all click beetles collected. The subdominant species are *Drasterius atricapillus*, *Dicronychus nigropunctatus*, and *Agriotes oxianus*.

Scarabaeidae. During research in the biocenoses of Lower Zeravshan, 31 species of lamellar beetles were discovered (together with 32 subspecies), belonging to eight subfamilies, 13 tribes, 19 genera. Two species (*Lethrus rosmarus*, *Pentodon brachypterus*) are endemic to Central Asia, two species (*Amphimallon sogdianum* and *Melolontha afflicta afflicta*) are among the endemic species of Uzbekistan.

In terms of species diversity, the subfamily Scarabaeinae clearly dominates (nine species, 28%). Representatives of the subfamily Melolonthinae make up 22% of all species (seven species). The fauna of the subfamilies Rutelinae and Valginae includes only one species each. However, the share of subfamilies in terms of the abundance of individuals differs significantly from their share in species diversity. By this indicator, the subfamily Cetoniinae has a clear advantage, accounting for 35% of all beetles collected.

When analyzing the species composition of the fauna of lamellar beetles by tribe, no obvious superiority of any tribes was observed. The largest share falls on representatives of the tribe Melolonthini, and they account for 15.6% of all species (five species). Also among the dominant tribes are the tribes Aphodiini, Cetoniini, and Scarabaeini (each 12.5%, four species). The tribes Anomalini, Valgini, and Onitini have one species each, and their share of the fauna is 3.1% (each). The share of tribes in species diversity and in the abundance of individuals does not coincide (Fig. 4).

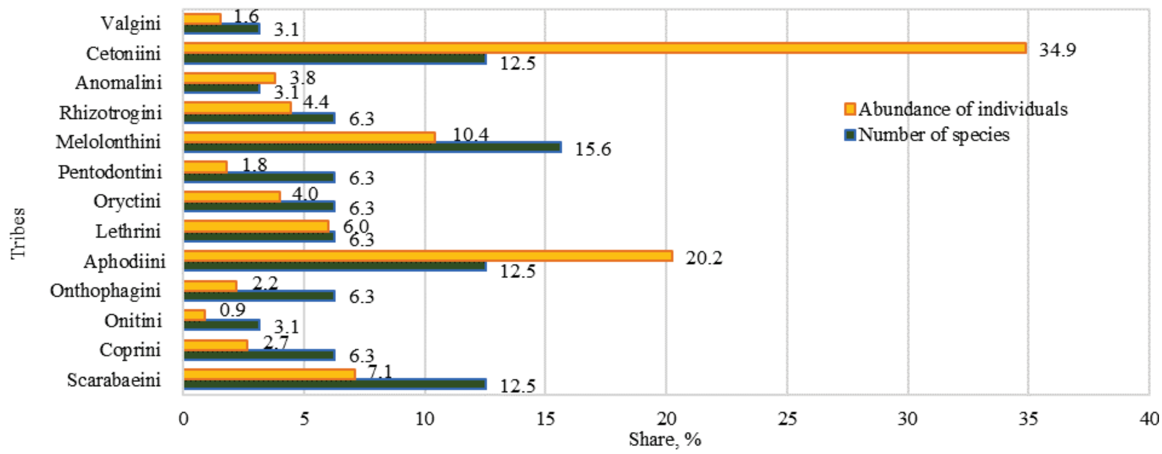

Fig. 4. Proportion of different tribes in the fauna of lamellar beetles by number of species and number of individuals

In general, the fauna of lamellar beetles is dominated by the species *Oxythyrea cinctella* (dominance rate 22.4%), *Acrossus rufipes* (9.8%), *Bodilus caspius* (5.6%) and *Tropinota hirta* (5.6%), and the species *Lethrus rosmarus* (4.7%), *Cetonia aurata* (4.4%), *Acrossus luridus* (4.2%), *Phyllopertha horticola* (3.8%) and *Melolontha hippocastani* (3.6%) are subdominant species. The species *Scarabaeus sacer*, *Onitis humerosus*, *Teuchestes fossor* and *Pentodon brachypterus* are scarce species, their dominance rate is less than 1%.

No noticeable differences in the species composition of lamellar beetles were detected between desert biocenoses and agrocenoses although *Pentodon brachypterus* and *Teuchestes fossor* were caught only in desert bicenoses, *Polyphylla alba* were collected only in agrocenoses. However, in our collections, these species are very few in number, and therefore, the statement about their association with certain biocenoses is not appropriate. In general, lamellar beetles, due to their good patching ability, actively migrate to more distant biocenoses.

Dynamics of the number of herpetobionts. Determination of seasonal fluctuations in the number of herpetobions was carried out using light traps. Although there are many flightless species among ground beetles and darkling beetles, studies have noted that fairly large beetles that cannot fly also crawl toward the light. Especially, ground beetles, which lead a predatory lifestyle, arrive intensively, which is explained by the fact that they feed on various insects that fall into these traps. Quite a lot of darkling beetles crawl or fly into the light, even large species. It should be noted that although the practice of using light traps was not particularly used when analyzing the numbers of darkling beetles and ground beetles, the number of these beetles among the captured insects was quite large.

In the biocenoses of the Lower Zeravshan, a noticeable increase in the number of herpetobionts is observed in the first days of June. The first high number of beetles was observed on June 1 (2022), and the number of insects caught in the trap on this day was 492 individuals. But subsequently there is a decrease in the number of beetles. The maximum number of herpetobiont beetles was recorded on July 3. During this period, the number of beetles caught in the trap in one night was 749 individuals. During this period, relative air humidity and atmospheric pressure were the lowest. But the next day, a sharp increase in wind led to a sharp decrease in the number of insects in the traps (Fig. 5).

Seasonal fluctuations of representatives of the families Carabidae, Elateridae, Staphylinidae and Tenebrionidae occur almost in parallel, while fluctuations in the number of representatives of the Scarabaeidae family do not correspond to those of the above families, and the maximum value is observed at the end of July.

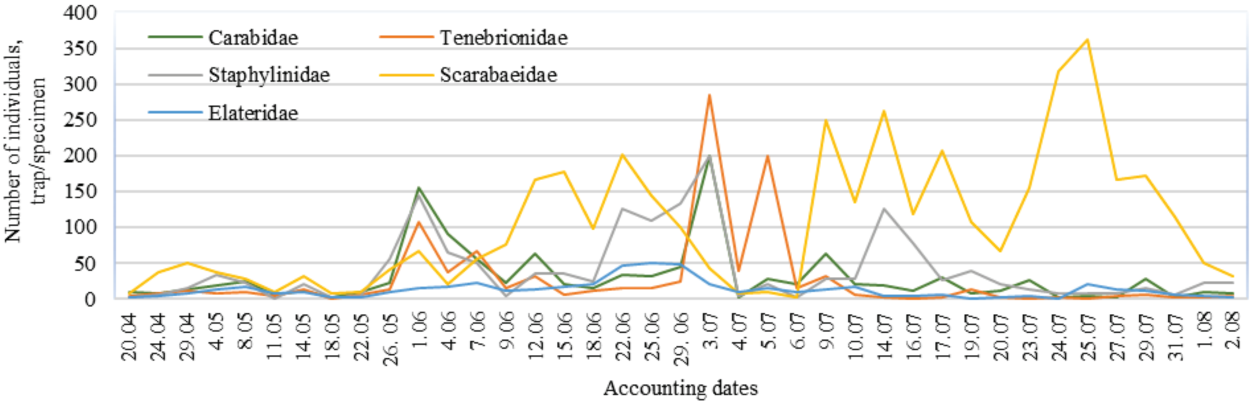

Fig. 5. Changes in the number of herpetobionts during the season (based on light traps) (2022)

Among the herpetobionts caught in light traps, representatives of the lamellar family (Scarabaeidae) dominate. The number of beetles of this family caught during the season was 3,947 (48% of all herpetobionts) specimens. The number of lamellar beetles reached significantly higher values in April. But at the beginning of May, their number decreased somewhat, and by the end of May, it began to grow again. In the second half of June, the density of these beetles reached significantly higher values, and during this period, the number of beetles caught in one light trap reached up to 200 individuals. In general, the maximum value of the number of lamellar beetles occurred in the third decade of June, and during this period, the number of beetles caught in one trap reached 362 individuals.

Of all the beetles caught in the traps, 19.1% (1567 specimens) were insects belonging to the family of rove beetles (Staphylinidae). Rove beetles are small beetles with a well-developed ability to fly. During the season, the number of rove beetles reached its maximum value three times. The first maximum value occurred at the beginning of June, and during this period, the number of insects caught in 1 trap was 145 specimens. But the highest value of their numbers was recorded on July 3 (200 insects were caught in one trap). The third maximum value of their number occurs in mid-July (July 14).

Representatives of the family Carabidae accounted for 14.2% of all beetles (1164 specimens). Ground beetles are among the most numerous beetles in biocenoses. However, due to the fact that many of their representatives have lost the ability to fly, they do not fall into light traps. The traps mainly attract ground beetles of smaller and medium sizes. However, despite this, based on the number of beetles caught in traps, conclusions can be drawn about the seasonal dynamics of the carabid fauna as a whole. The highest numbers of ground beetles occur in June and early July.

In terms of the number of individuals caught, the family of darkling beetles (Tenebrionidae) ranks next, and during the season, representatives of this family numbered 1031 individuals (12.5% of all herpetobionts). It should be noted that in the main part of the season the abundance of representatives of this family is significantly lower compared to other taxa. But on July 3, a sharp increase in the number of darkling beetles was observed; the number of beetles caught that day in traps was 285. In general, among the darkling beetles that came to light traps, the largest numbers were representatives of the genera *Scleropatrum* and *Gonocephalum*.

Among the herpetobionts, the smallest group was click beetles (Elateridae), which made up 6.2% of all beetles caught. However, this situation does not indicate the population density of species belonging to this group. Click beetles, among herpetobionts, are a group with fewer species, and only 10 species are common in the study area. Although the population density of these species is quite high, their numbers are relatively small compared to the total number of herpetobionts. Click beetles have good flight skills and rush towards light traps in large numbers. Seasonal fluctuations in the number of these beetles are quite stable and change little during the season. Their greatest number occurs at the end of June.

A weak positive correlation was revealed between the number of herpetobionts and air temperature and a weak negative correlation between the number of herpetobionts and air humidity and atmospheric pressure. The influence of physical air parameters on the number of beetles is most pronounced in Scarabaeidae and Staphylinidae (Fig. 6–8). However, in Carabidae and Tenebrionidae, the dependence of the number of beetles on air temperature and atmospheric pressure has not been revealed.

Discussion

The lower part of the Zeravshan Valley is particularly affected by global warming and anthropogenic pressure. Unfortunately, there have been no special faunal studies of this region in the past, which does not make it possible to compare the data obtained. But compared to neighboring regions, the diversity of beetles is much lower. Thus, in the Nurata Nature Reserve and adjacent territories, 105 species of ground beetles, 61 species of darkling beetles, and 47 species of lamellar beetles have been recorded (Daminova, 2011). On the Zeravshan Range, the number of ground beetle species is 81 species (Khalimov, 2023). But these territories are mountainous territories. In the desert territories of four regions of Uzbekistan (Jizzakh, Navai, Kashkadarya, and Surkhandarya), which is much larger than the territory of Lower Zeravshan, 44 species of darkling beetles were identified (Egorov & Rakhimov, 2015). In the Central region of Saudi Arabia, 26 species of darkling beetles have been recorded (Aldryhim et al., 1992). In the Patagonian region in southern Argentina, where semi-desert steppes and shrubs predominate, 30 species of darkling beetles are recorded (Sackmann & Flores, 2009). The closest climatic conditions to Lower Zeravshan are in Southern Kazakhstan. Thus, in South-Eastern Kazakhstan, 27 species of ground beetles were identified (Jasim et al., 2024) and 27 species of darkling beetles (Schawaller, 2003).

The desert is home to many families of beetles, each with unique characteristics that allow them to survive in harsh desert conditions. In our studies, the environments of the studied families showed the greatest diversity in darkling beetles (Table 1). Tenebrionids are a prominent component of the fauna of arid cenoses, demonstrating special adaptation to the extreme climatic conditions of these environments (high temperature and aridity). These adaptations include, for example, different morphological traits (such as long legs and a subelytral cavity), finely tuned life cycles, ecological specialization, and diurnal and seasonal activity patterns (Fattorini, 2023). In our studies, the diversity of darkling beetles in desert biotopes was much higher compared to agrocenoses and populated areas, which once again proves the adaptability of many darkling beetle species to more arid conditions. This agrees with the opinion that an increase in irrigated land over time leads to a simplification of the darkling beetle community, and vice versa, an increase in the diversity of ground beetles (Pardo et al., 2008). Although, in our studies, the diversity of ground beetles in desert biotopes and agrocenoses was close.

The family Elateridae is the least diverse (10 species). Although no lists of the species composition of click beetles have been compiled for neighboring regions, the distribution of 14 species is indicated for Southern Uzbekistan (Prosvirov & Kovalenko, 2015). And in Eastern Kazakhstan, where the amount of precipitation is 2–3 times higher, the diversity of click beetles is quite high and amounts to 54 species (Ormanova, 2017).

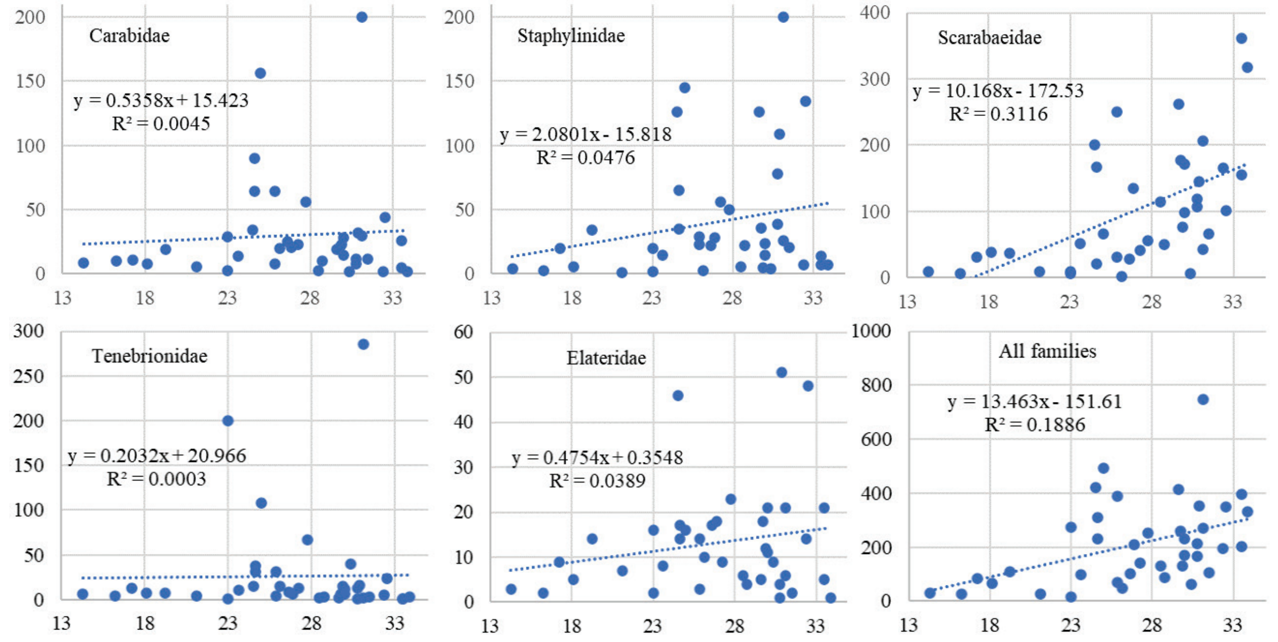

Fig. 6. Relationship between the number of herpetobionts and air temperature: on the abscissa axis, air temperature; along the ordinate – the number (individuals) of beetles per 1 light trap

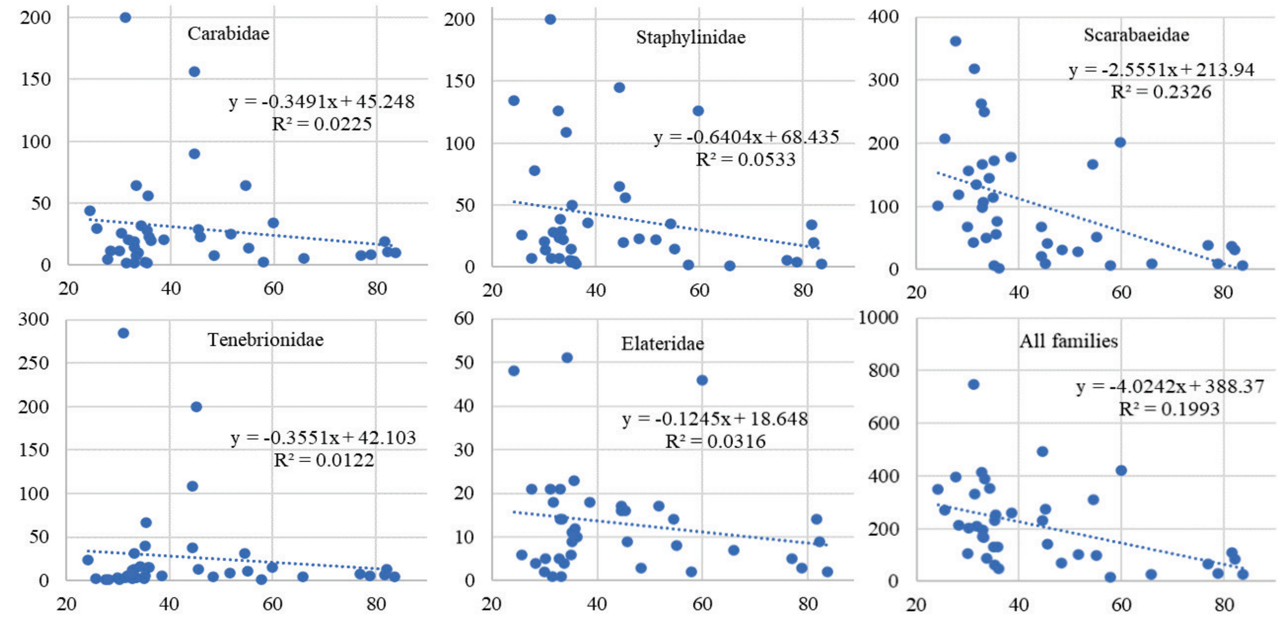

Fig. 7. The relationship between the number of herpetobionts and relative air humidity: on the abscissa axis, air humidity; along the ordinate – the number (individuals) of beetles per 1 light trap

The heterogeneous topography, soils, and climatic characteristics of many arid ecosystems, coupled with the isolation of critical resources such as water, also result in high levels of endemism. In our studies, the highest level of endemism is manifested in darkling beetles (13 endemics of Central Asia and two endemics of Uzbekistan). Among the lamellar beetles there is one endemic of Central Asia and two endemics of Uzbekistan, among the ground beetles there are four endemics of Central Asia, and among the click beetles there are two endemics of Central Asia. Although we are unable to compare data due to the lack of previous research for this region, it can be argued that biodiversity is declining. It should be noted that in our research over five years, special searches for the Red Book species of ground beetles – *Anthia mannerheimii* Chaudoir, 1842, were not successful. The distribution of this species in this region is noted in the Red Book of Uzbekistan (Red Book of Uzbekistan, 2019). Apparently, this species has already disappeared from the fauna of the Republic. The same situation applies to the darkling beetle *Sternodes caspicus*. Our entomological collection contains more than 40 specimens of this species, collected in the mid-20th century from the research region. In addition, several more species of darkling beetles, especially large ones, available in museum exhibits, were not recorded by us in the field. It has been argued that beetle size may serve as an indicator of habitat degradation (Eyre et al., 2013). Using ground beetles as an example, it has been proven that a decrease in the size of beetles warns of global climate change and rising temperatures (Tseng et al., 2018). It is also argued that global climate change, chemical treatment of agricultural land, unregulated grazing, recreational pressure, and large-scale construction can lead to the extinction of many populations of rare species of herpetobiont beetles (Putchkov & Brygadyrenko, 2022).

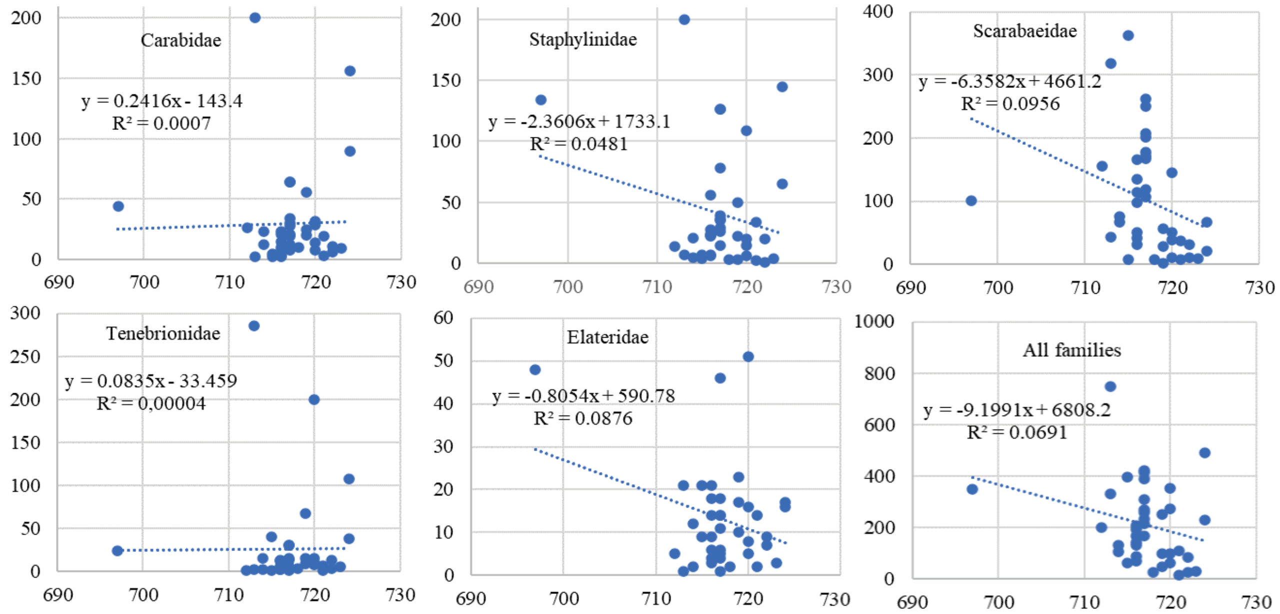

Fig. 8. Relationship between the number of herpetobionts and atmospheric pressure: along the abscissa axis, atmospheric pressure; along the ordinate – the number (individuals) of beetles per 1 light trap

Over the past 40 years, the average annual temperature in Lower Zeravshan has increased by 1.5 °C, and the amount of precipitation has decreased by 30.8 mm, which negatively affects the vegetation cover of the region (Akhmedov et al., 2022). Declining precipitation and increasing temperatures pose a serious threat to the water balance and biodiversity of natural ecosystems (Kirichenko-Babko et al., 2020). Despite adaptation to extreme temperatures, species living in arid environments may be particularly vulnerable to rising temperatures due to physiological constraints that limit the evolution of species' tolerance to high temperatures (Barrows, 2011). However, there are some opinions that rising temperatures may favor some thermophilic species in certain areas, allowing them to expand their range and diurnal and annual activity rhythms (Fattorini, 2023).

Besides, the desert areas of the region, especially, suffer greatly from grazing by cattle and sheep. Although there is evidence that moderate grazing in meadow biocenoses helps to increase the diversity of herpetobiont beetles (Barber et al., 2022; Pozsgai et al., 2022), in deserts, due to the poverty of the phytocenosis, there is a clear negative impact of grazing by domestic animals on the biodiversity of herpetobiont beetles.

Based on the above, it will be promising to study the ongoing changes and rearrangements in the fauna of the region. We hope that our data will serve as a point of departure for such studies for Lower Zeravshan.

Conclusion

Thus, the species composition of herpetobiont beetles (Carabidae, Tenebrionidae, Elateridae, Scarabaeidae) of the Lower Zeravshan consists of 132 species. The carabid fauna of the region is represented by 43 species belonging to nine subfamilies, 19 tribes, and 28 genera. For the fauna of the Republic, two species were recorded for the first time (*Syntomus obscuroguttatus* and *Scarites subcylindricus*). The dominant ground beetle species are *Calathus ambiguus*, *Machozetus lehmanni*, *Harpalus distinguendus*, *Scarites bucida* and *Machozetus concinnus*, and *Scarites terricola*, *Megacephala euphratica*, *Amara aenea*, *A. ovata* and *Harpulus rubripes* are the subdominant species.

The darkling beetle fauna of the studied region includes 46 species belonging to three subfamilies, 16 tribes, and 30 genera. For the first time, five species were recorded for the fauna of the Republic of Uzbekistan (*Cyphogenia lucifuga*, *Trigonoscelis apicalis*, *Colpotus sulcatus*, *Tribolium destructor*, *Pentaphyllus chrysomeloides*). In the fauna of darkling beetles *Adesmia planidorsis*, *Stenosis sulcicollis*, *Scleropatrum breviusculus*, *Cyphogenia lucifuga*, *Trigonoscelis apicalis*, *Scleropatrum seidlitzi*, *Zophosis scabriuscula* and *Ocnera pilicollis* are the dominant species, while the species *Tentyria gigas*, *Scleropatrum hirtulum*, *Cyphogenia limbata* and *Blaps scutellata* are subdominant species.

The fauna of ground beetles and darkling beetles of the Lower Zeravshan consists of two species complexes that differ sharply from each other – xerophilic (inhabiting desert biocenoses) and hygromesophilic (inhabiting agricultural landscapes). The similarity coefficients of the fauna of these two types of biocenoses are very low (for ground beetles: Jaccard/Chekanovsky-Sørensen – 0.098/0.078; for darkling beetles: Jaccard/Chekanovsky-Sørensen – 0.057/0.13).

The fauna of click beetles is represented by 10 species belonging to four subfamilies and seven genera. The dominant species of click beetles are *Drasterius figuratus*, *Melanotus acuminatus*, *Agriotes meticulosus* and *Cardiophorus hauseri*, and the subdominant species are *Drasterius atricapillus*, *Dicronychus nigropunctatus*, and *Agriotes oxianus*.

The fauna of lamellar beetles consists of 31 species (32 with subspecies), belonging to eight subfamilies, 13 tribes, and 19 genera. The dominant species are *Oxythyrea cinctella*, *Acrossus rufipes*, *Bodilus caspius* and *Tropinota hirta* and the subdominant species are *Lethrus rosmarus*, *Cetonia aurata*, *Acrossus luridus*, *Phyllopertha horticola* and *Melolontha hippocastani*.

In agrocenoses, a significant increase in the number of herpetobionts was observed in the first days of June. But their maximum number was observed in early July. There is a weak positive correlation between the number of herpetobiont beetles and air temperature, and between relative humidity and atmospheric pressure and the number of beetles there is a weak inverse correlation.

It has been established that while seasonal fluctuations in representatives of the families Carabidae, Elateridae, Staphylinidae, and Tenebrionidae occur almost in parallel, in contrast, fluctuations in the number of representatives of the Scarabaeidae family do not correspond to the above pattern, and the maximum value is observed at the end of July. The presented ecological and faunal study of herpetobiont beetles of the Lower Zeravshan is of a preliminary nature. These studies will be continued and expanded. In addition, it is necessary to study the state of populations of rare and small species, with their subsequent inclusion in the Red List of the Republic.

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