DEVELOPMENT STABILITY OF THE SKULL OF TWO RODENT SPECIES (MAMMALIA, RODENTIA) IN ANTHROPOGENIC AND THE ENVIRONMENT OF CENTRAL CAUCASUS MOUNTAINS

[a]FATIMAT A. TEMBOTOVA, [b]ALBINA H. AMSHOKOVA, [c]EKATERINA P. KONONENKO, [d]EKATERINA A. KUCHINOVA

[a]Corresponding member of the Russian Academy of Sciences, Dr.Sci.Biol., director of Institute of ecology of mountain territories of A.K. Tembotov of RAS ,Russia.
[b]Candidate of Biology, senior research associate of laboratory of ecology and evolution of vertebrate animals,Russia.
[c]Candidate of Biology, head of the laboratory of ecology and evolution of vertebrate animals,Russia.
[d]Research associate of laboratory of ecology and evolution of vertebrate animals,Russia.
[a,b,c,d]Tembotov Institute of Ecology of Mountain Territories of Russian Academy of Science360051 KBR, Nalchik, I. Armande St., 37a
Email: [a]h.a.amshokova@mail.ru [b]alsu_zarifovna@mail.ru, [c]info@ores.su, [d]global@ores.su

Abstract. For assessment of individual developmental stability in two species – A. uralensis and M. musculus under different ecologic-geographical conditions of the Central Caucasus the levels of fluctuating asymmetry of skull phenes expression in 4 samples for each species were studied. Impact of both anthropogenic pollution and a complex of environment conditions concerning locality altitude, was also studied. It is revealed that M. musculus as compared with A. uralensis, is characterized by the increased level of fluctuating asymmetry suggesting that the impact on M. musculus sampling is more smoothed because of the species dwelling in human houses. Anthropogenic pollution (pollution by agrocenosis pollutants) is the leading destabilization factor of the skull development in both species. In natural ecosystems weak positive correlation between the increase of asymmetry level and temperature lowering in middle mountains is revealed in M. musculus; positive correlation between the increase of asymmetry level and increase of environment humidity is also revealed in A. uralensis

Keywords: A. uralensis, M. musculus, non-metric bilateral skull characters, the fluctuating asymmetry, correlation and factor analyses, Central Caucasus.

1 Introduction

Increase in the general anthropogenic load of the environment leads to essential change of habitation conditions. In this regard studying of the state of populations of the live organisms which are under the anthropogenic impact and also the research of processes of adaptations is important as live organisms bear the maximum information on their habitats. Similar researches are especially important in the conditions of mountain territories owing to specific conditions and fragility of mountain ecosystems. In most regions of the Central Caucasus the agricultural transformation of territories connected with use of inorganic fertilizers and pesticides acts as the main form of anthropogenic activity as dictates need of control of results of anthropogenic influence.

For assessment of a condition of natural populations the method of assessment of stability of development in the size of indicators of the fluctuating asymmetry of morphological features is widely used (Baranov, 2003).

The fluctuating asymmetry is shown in the insignificant not directed differences between the parties which have no independent adaptive value and don't exert notable impact on viability of individuals. Level of the fluctuating asymmetry increases at a deviation of parameters of the environment from optimum conditions that gives the chance of detection of the populations living in the adverse environment.

The analysis of publications shows that the results received when studying influence of stress factors on level of the fluctuating asymmetry are contradictory. So according to a number of authors this indicator increases at stressful influences (Shadrina et al., 2003; Vasilyeva et al., 2003; Yalkovskaya et al., 2016; Parsons, 1990; Moller, Pomiankowski, 1993; Oleksyk et al., 2004; Øxnevad et al., 2002) whereas the similar effect isn't found by other researchers (Gileva, Kosareva, 1995; Gileva, Nokhrin, 2001; Owen, McBee, 1990; Kellner, Alford, 2003; McCoy, Harris, 2003).

So, we have shown comparison of levels of the fluctuating asymmetry of craniological measurements at house mice from seven localities of Sverdlovsk region with the different level of technogenic pollution that any of the studied craniological characters from the polluted territories doesn't find growth of the fluctuating asymmetry in mice (Gileva, 1997). The analysis of not metric signs of a skull of the pygmy wood mouse occupying in zones of the East Ural radioactive trace is pointed, on the contrary, to increase of the FAnm index at young females of impacting samples in comparison with control whereas at adult females his decrease is noted. With age in impacting sites authors connect decrease in FAnm with more intensive rejection of asymmetric animals in zone EURT (Vasilyeva et al., 2003).

In this regard the research of reaction of two species, widely widespread and numerous in Central Caucasus – pygmy wood mouse (Apodemus uralensis Pallas, 1811) and the house mouse (Mus musculus Linnaeus, 1758) on action as the natural factors connected with area height and anthropogenic factors is of special interest.Research objective – to compare stability of skull development of two species of rodents which are widely extended in the Caucasus, one of whom synantropic, a house mouse (Mus musculus), the second – the pygmy wood mouse (Apodemus uralensis) living under natural conditions middle mountains and highlands in anthropogenic and an environment of Central Caucasus.

2 Methodology

Material by both types gathered at the same time in the same years on Central Caucasus Mountains: middle mountains – the surrounding item Elbrus (1800 m above sea-level), the foothills – the surrounding village of Bedyk (950 m above sea-level), the surrounding village of Psynadakha (700 m above sea-level), surrounding Nalchik (550 m above sea-level). Vicinities of the item Elbrus and Nalchik belong to natural biotopes, and the surrounding villages of Bedyk and Psynadakha to anthropogenic (a biotope near agrocenosis) (fig. 1).

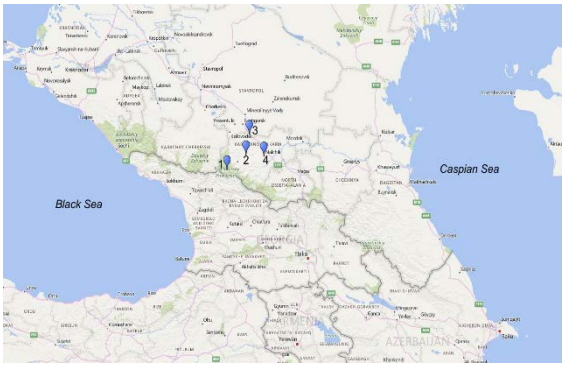

Fig. 1. Sites of sampling: 1 –environs of Elbrus village; 2 – environs of Bedyk village; 3 – environs of Psynadakha village; 4 – environs of Nalchik town.

Some physiographic characteristics of points of origin of material are provided in tab. 1.

Table 1. Some physiographic, climatic characteristics of places of origin of material on small forest and house mice on Central Caucasus Mountains

Material origin place	Above sea height, m	Average yearly temperature, ^{0}C	Average annual quantity of rainfall, mm	Gamma noise, μSv/h
middle mountains (1001-2000 m above sea-level)				
1. Surrounding p. Elbrus	1800	3.8	917	0.20
foothills (200-1000 m above sea-level)				
2. Surrounding v. Bedyk	950	7.9	785	0.22
3. Surrounding v. Psynadakha	700	8.6	630	0.17
4. Surrounding c. Nalchik	550	9.6	724	0.17

It is visible that gamma background level in all studied areas low (less than 0.5 μSv/h) and in the annex to the person is considered as normal, not defiant pathological changes in an organism.

In work adult animals whose relative age was determined by abrasion of molars were used. The volume of the studied material was on a small forest mouse –264, and on a house mouse – 192 copies of skulls of small animals.

The most part of the phenes used in work is taken from references (Vasilyev, etc., 1996; Sands, Yemelyanov, 2000; Vasilyeva, etc., 2003). The latin system of coding of phenes developed by I.A. Vasilyeva is assumed as a basis (Vasilyev, Vasyleva, 2009).

Communication of manifestation of phenes with a sex, age, with each other estimated on the basis of calculation of nonparametric coefficients of correlation of Spirmen then a small part of the signs which are strongly correlated with the specified factors was excluded from the further analysis (Vasilyev, 2005). By each look the analysis was carried out on 33 not metric signs of a skull.

However a part of the signs characteristic of a small forest mouse had other condition of sign at a house mouse, coincidence is noted on 21 signs from 33. The list of 33 signs is provided in fig. 2.

For assessment of level of the fluctuating asymmetry counted the average population index of the fluctuating asymmetry of S.E. as an average share of bilateral asymmetric manifestations of the hair dryer on sign at different individuals (Zakharov, 1987; Markowski, 1993).

Data processing was carried out by means of the PHEN 3.0 program (Vasilyev, 1995), by PAST (Hummer et al., 2001) and Statistics 10 programs. The importance of differences between selections was estimated by means of a method of nonparametric statistics of Kraskela-Wallice which is similar to the one-factorial dispersive analysis (Vasilyev, 2005).

For identification of influence of factors used the multiple-factor dispersive analysis (ANOVA). Existence of communication was established with use of the nonparametric correlation analysis (Nonparametrics, Gamma).

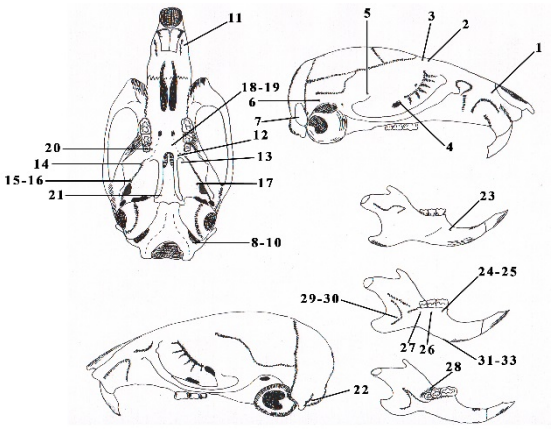

Fig. 2. An arrangement of phenes of not metric signs on a skull of a small forest mouse: 1 – the doubled preorbital opening (FPodu); 2 – an additional frontal opening ahead of main (FFracan); 3 – lack of a frontal opening (FFracan (-)); 4 – single orbital opening (FIO); 5 – single forward opening of a scaly bone (FTmacan); 6 – single opening of the temporal course (MeTm); 7 – lack of a window on a mastoidal bone (FeMs (-)); 8 – single hypoglossal opening (FHg); 9 – the trebled hypoglossal opening (FHgtr); 10 – side hypoglossal opening (FHgla); 11 – forward side maxillary opening (FPmla); 12 – a single opening in the basis of a wing-shaped shoot (FPT); 13 – the doubled opening in a wing-shaped pole (FRTI); 14 – single additional round opening (FPD); 15 – the doubled opening on a partition between oval and round openings (FLTIdu); 16 – the trebled opening on a partition between oval and round openings (FLTItr); 17 – an additional opening in the field of an oval opening from the ventral party in a wing-shaped pole (Fasac); 18 – single additional palatal opening (FPl); 19 – more than three openings on a palatal bone ((FPlmx)); 20 – a single small opening at the M3 level (FPLmn); 21 – side openings on the ventral surface of the main wedge-shaped bone (FBsla); 22 – multiple openings on an occipital bone in pole (FFsOc(mx)); 23 – an additional subchin opening ahead of main (FMTA); 24 – a single opening from lingval side of an alveolus of M1 (FMtlg); 25 – the doubled opening from lingval side of an alveolus of M1 (FMtlgdu); 26 – a single opening from lingval side of an alveolus of Sq.m (FMblg); 27 – the doubled opening from lingval side of an alveolus of M3 (FMblgpodu); 28 – the doubled opening in the Sq.m area on an internal surface (FPCdu (M2)); 29 – the doubled additional opening in a wing-shaped pole of the lower jaw (in connection-angular cutting) (FMbmst); 30 – more than three additional openings in a wing-shaped pole of the lower jaw (connection-angular cutting) (FMbmst(mx)); 31 – a single opening on "body" of the lower jaw (FOM); 32 – the doubled opening on "body" of the lower jaw (FOMdu); 33 – more than three openings on "body" of the lower jaw (FOMtr).

3 Results and Discussion

The lack of significant sexual distinctions when comparing level of the fluctuating asymmetry at both types has allowed uniting the corresponding selections of males and females for the further analysis.

For the purpose of identification of trans-species distinctions, without imposing of influence of various conditions of dwelling comparison is carried out by Kruskal-Wallis test for equal medians method of selections of small forest and house mice of the same habitats. Comparison has revealed reliable intergroup distinctions at multiple comparison (Nanosecond =40.83; d.f. =7; p <0.0001).Apparently from the table 2 the range of variation of the average level of the fluctuating asymmetry at a forest mouse (23.5-28.4) is wider at lower maximum value, than at house (27.1-30.2) that is confirmed by variability of coefficient of a variation.

Table 2. Levels of the fluctuating asymmetry (S.E., %) in populations of small forest and house mice of Central Caucasus Mountains

Selection		N	S.E.	CV%
small forest mouse				
1.	Surrounding p. Elbrus	122	24.2 ± 0.69	31.6
2.	Surrounding v. Bedyk	54	26.8 ± 1.04	28.6
3.	Surrounding v. Psynadakha	47	28.4 ± 1.41	34.0
4.	Surrounding c. Nalchik	41	23.5 ± 1.62	44.2
house mouse				
5.	Surrounding p. Elbrus	51	30.2±0.85	20.1
6.	Surrounding v. Bedyk	50	26.5±1.02	27.2
7.	Surrounding v. Psynadakha	49	29.6±0.97	23.0
8.	Surrounding c. Nalchik	42	27.1±1.31	31.3

Note: N – volume of selections, S.E. – a standard mistake, CV, % – variation coefficient

When comparing selections of the house and forest mice coming from the same geographical points taking into account height of the area it is revealed that the level of the fluctuating asymmetry practically in all selections of house mice above, than at forest, however, reliable trans-species distinctions have been found only in middle mountains (item Elbrus) (tab. 2, 3).

Table 3. Assessment of the importance of differences on the level of the fluctuating asymmetry between selections of A. uralensis and M. musculus of Central Caucasus Mountains (Tuuki-Kramer's test). The top triangular matrix – values of probabilities of p), and the lower triangular matrix – values of the posteriori pair Q-test of Tuuki-Kramer

Selection	small forest mouse				house mouse			
	1	2	3	4	5	6	7	8
1		ns	ns	ns	***	ns	**	ns
2	2.40		ns	ns	ns	ns	ns	ns
3	3.82	1.42		*	ns	ns	ns	ns
4	0.61	3.01	4.43		***	ns	***	ns
5	5.42	3.02	1.61	6.04		ns	ns	ns
6	2.06	0.34	1.76	2.68	3.36		ns	ns
7	4.94	2.54	1.12	5.55	0.49	2.87		ns
8	2.66	0.26	1.16	3.27	2.77	0.59	2.28	

Note: Small forest mouse: 1. surrounding item Elbrus, 2. surrounding village of Bedyk, 3. surrounding village of Psynadakha, 4. surrounding Nalchik; House mouse: 5. surrounding item Elbrus, 6. surrounding village of Bedyk, 7. surrounding village of Psynadakha, 8. surrounding Nalchik. Significance value of intergroup distinctions: * p <0.05; ** p <0.01; *** p <0.001.

The following stage for realization of a goal has carried out the correlation analysis for identification of communication of variability of the fluctuating asymmetry with a number of physiographic factors of the environment and existence of anthropogenic influence (pollution by pesticides) in the conditions of agrocenosis.

Assessment of communication of stability of skull development of small forest and house mice with natural and anthropogenic factors of the environment. Existence of communication was established with use of the nonparametric correlation analysis. The fluctuating asymmetry (tab. 2) increases among: at a small forest mouse – 1. Nalchik; 2. Elbrus, 3. Bedyk, 4. Psynadakha; at a house mouse – 1. Bedyk, 2. Nalchik, 3. Psynadakhaa, 4. Elbrus.

Connection of S.E. with temperature of habitats (tab. 4) is established weak correlation for a house mouse, the fluctuating asymmetry of a skull of a look is higher in middle mountains, i.e. at the difference of heights more than 800 m above sea-level.

Table 4. Correlation of the fluctuating asymmetry of a skull of mouse-like rodents with a habitat temperature in the conditions of Central Caucasus Mountains.

Specie	N	Gamma - correlation	p-level
House mouse	151	0.39	0.000
Small forest mouse	96	0.06	0.414

Connection of S.E. with humidity of habitats (tab. 5) is established weak correlation only for a forest mouse, the fluctuating asymmetry of a skull of a look is higher in the middle mountains which are characterized by the maximum humidity (tab. 1).

Table 5. Correlation of the fluctuating asymmetry of a skull of mouse-like rodents with humidity of the habitat in the conditions of Central Caucasus Mountains.

Specie	N	Gamma - correlation	p-level
House mouse	151	0.041	0.452
Small forest mouse	96	0.25	0.000

Connection of S.E. with anthropogenic loading (pollution by pesticides) in places of dwelling (tab. 6) is established for both species of rodents.

Table 6. Correlation of the fluctuating asymmetry of a skull of mouse-like rodents from anthropogenic loading (pollution by pesticides) in habitats in the Central Caucasus

Specie	N	Gamma - correlation	p-level
House mouse	151	0.48	0.000
Small forest mouse	96	1.00	0.000

However at a house mouse correlation of S.E. with an anthropogenic factor average while the maximum value of the S.E. level is noted under natural conditions (the surrounding item Elbrus). At a small forest mouse dependence of stability of skull development on existence of anthropogenic loading absolute, the asymmetry of a skull is higher in the conditions of agrocenosis (the surrounding village of Psynadakha and the item Bedyk).

For specification of the revealed correlation of asymmetry with high-rise and anthropogenic factors the two-factor dispersive analysis (tab. 7) has been carried out. Significant communication

of level of the fluctuating asymmetry with a factor "anthropogenic influence" whereas "look" and a combination of these two factors don't exert significant impact is revealed.

Table 7. Results of the two-factor dispersive analysis of influence of factors "look" and "anthropogenic influence" on the S.E. levels of two types

Factor (variability source)	Sum of squares	Number of freedom degree, *d.f.*	Average square	Fisher criteria, *F*	Importance level, *p*
Specie (A)	250.4	1	250.4	3.2	0.08
Anthropogenic pollution (B)	614.4	1	614.4	7.8	0.006
Interaction (AxB)	63.4	1	63.4	0.81	0.37
Intra group variability	13743	175	78.5		
General variability	14667.9	178			

The lack of selection of middle mountains with similar type of pollution (pesticides of agrocenosis) hasn't allowed establishing influence of this factor on asymmetry of a skull of both types. However the dispersive analysis shows that at a forest mouse the level of asymmetry is almost identical in the foothills and middle mountains at a difference of heights more than 1000 m above sea-level (selections Nalchik and the item Elbrus). Distinctions at a house mouse from the same two habitats are considerable.

During the carried-out comparative analysis it is revealed that significant increase in level of the fluctuating asymmetry under the influence of height factor only at a house mouse, and in the conditions of anthropogenic pollution – at both types is observed. At the same time differences between selections of a forest mouse are expressed more brightly, than at house. Variability amplitude under the influence of height factor at a forest mouse already than at house, and at house opposite variability amplitude under the influence of a pollution factor already than at forest.

The obtained data on asymmetry of a skull house and small forest mice of Central Caucasus Mountains significantly differ from those for Central Russia and South Ural (Vasilyev, etc., 2000; Vasilyeva, etc., 2003) in a pollution zone radionuclides of the territory of the Totsky radioactive trace (TRAS) and the East Ural Radioactive Trace (EURT). At the forest mouse living in zone VURS increase of the index of the fluctuating asymmetry it is noted at young females of a forest mouse (26.02±0.80), with age the index of the fluctuating asymmetry decreases and makes – 20.86±1.75. At females from control groups the index of the fluctuating asymmetry is low and doesn't change with age: 23.22±0.77 and 23.39±1.32 (Vasilyeva, etc., 2003).

4 Conclusion

1. Level of the fluctuating asymmetry at a sinantrop, a house mouse, above, than at forest in spite of the fact that spends the most part of adverse season in more smoothed conditions (temperature, humidity, etc.) in comparison with a small forest mouse, and in middle mountains of Central Caucasus Mountains at the height of 1500 m above sea-level and above a house mouse isn't moved in the nature and all the year round lives in the dwelling of the person. Also rather low coefficient of a variation at the high level of the fluctuating asymmetry attracts attention that indicates destabilization of process of individual development of the majority of individuals in selections of a house mouse. It is possible to assume that the house mouse is to a lesser extent subject to action of selection in connection with dwelling in more favorable conditions. Possibly, a little smaller values of the fluctuating asymmetry in selections of a "wild" forest mouse are connected with more intensive rejection of "asymmetric" animals.
2. The most adverse are conditions of middle mountains for both types, at the same time for a house mouse as the destabilizing factor decrease in temperature in middle mountains, and for small forest – increase in humidity middle mountains acts.
3. Pollution by pollutant (use of chemicals in agrocenosis) makes an adverse effect on skull development as a sinantrop, a house mouse, and "wild living" a small forest mouse.

Literature:

1. Baranov V.Yu. (2003). A research of populations of fishes in the conditions of water ecosystems with various degree of anthropogenic loading,Problem of global and regional ecology, Yekaterinburg. Pp. 6 – 9.
2. Vasilyev A.G. (1995). Package of the PHEN 3.0 application programs. [Electronic resource] – Access mode: (http:,ecoinf.uran.ru).
3. Vasilyev A.G., Vasilyeva I.A., Bolshakov V.N. (1996). Phenetic monitoring of populations of a red vole (Clethrionomys rutilus Pall.) in a zone of the East Ural Radioactive trace,Ecology. No. 2, Pp. 117-124.
4. Vasilyev A.G., Boev V.M., Gileva E.A., etc. (2000). Remote ecologic-genetic consequences of radiation incidents: Totsky nuclear explosion (Orenburg region, 1954). 2 ed.rev. Yekaterinburg: Yekaterinburg publishing house, Pp. 288.
5. Vasilyeva I.A., Vasilyev A.G., Lyubashevsky N.M., Chibiryak M.V., Zakharov E.Yu., Tarasov O.V. (2003). Phenogenetic analysis of populations of a small forest mouse (Apodemus uralensis Pall.) in a zone of influence of the East Ural radioactive trace//Ecology. No. 6, Pp. 445-453.
6. Vasilyev A.G. (2005). Epigenetic bases of phenetics: on the way to a population meronomy. Yekaterinburg: Akademkniga publishing house, Pp. 640.
7. Vasilyev A.G., Vasilyeva I.A. (2009). Homological variability of morphological structures and epigenetic divergence of taxons: Bases of a population meronomy. M.: KMK,Pp. 511.
8. Gileva E.A., Kosareva N.L.(1995). Reduction of the fluctuating asymmetry at house mice in the territories polluted by chemical and radioactive mutagens,Ecology. No. 3, Pp 237-240.
9. Gileva, E.A. (1997). Eco-genetic monitoring by means of rodents (the Ural experience). Yekaterinburg: Publishing house Ural un-that, Pp. 106.
10. Gileva E.A., Nokhrin D. Yu. (2001). The fluctuating asymmetry of craniometric signs at the East European vole from zones of radiation trouble,Ecology. No. 1, Pp 44-49.
11. Zakharov V.M. Asymmetry of animals. M. Nauka. 1987.Pp. 216.
12. Peskov V.N., Yemelyanov of I.G. (2000). Phenetic and phenogeography of a water vole (Arvicola terrestris),Vestn. Zoology.No. 3, Pp. 39-44.
13. Shchadrina E.G., Volpert Ya.L., Danilov V. A., Shchadrin D.Ya. (2003). Biondication of impact of the mining industry on land ecosystems of the North. Novosibirsk: Science. 2003. 105 pages.
14. Yalkovskaya L.E., Fominykh M.A., Mukhacheva S.V., Davydova Yu.A., Borodin A.V. (2016). The fluctuating asymmetry of cranial structures of rodents in a gradient of industrial pollution,Ecology.No. 3, Pp. 213-220.
15. Hammer Ø., Harper D.A.T., Ryan P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Paleontologia Electronica.. V. 4. No 1, P 9.
16. Kellner J.R., Alford R.A. The ontogeny of fluctuating asymmetry ,Amer. Natur. V. 161, No. 6, Pp. 937-947.
17. Markowski J. (1993). Fluctuating asymmetry as an indicator for differentiation among roe deer Capreolus capreollus populations , Acta Theriol. V.38 (Suppl. 2), Pp. 19–31.
18. McCoy K.A., Harris R.N. (2003). Integrating developmental stability analysis and current amphibian monitoring techniques: an experimental evaluation with the salamander *Ambystoma maculates* , HerpetologicaV. 59, No.1,Pp. 22-36.
19. Moller A.P., Pomiankowski A. (1993). Punctuated equilibria or Gradual Evolution: Fluctuating Asymmetry and Variation in the Rate of Evolution ,J. Theor. Boil. V. 161, Pp. 359 - 367.
20. Oleksyk T.K., Novak J.M., Purdue J.R., Gashchak S.P., Smith M.H. (2004). High levels of fl uctuating asymmetry in

populations of Apodemus flavicollis from the most contaminated areas in Chornobyl , J. Environmental Radioactivity. V. 73, Pp. 1–20.
21. Øxnevad S.A., Heibo E., Vollestad L.A. (2002). Is there a relationship between fluctuating asymmetry and reproductive investment in perch (Perca fluviatilis)? Can. J. Zool. V. 80, No.1, Pp. 120-125.
22. Owen R.D., McBee K. (1990). Analysis of asymmetry and morphometric variation in natural populations of chromosome-damaged mice ,Texas J. Sci .V. 42, No. 4, Pp. 319–332.
23. Parsons P.A. (1990). Fluctuating asymmetry: an epigenetic measure of stress , Biol. Rev. Vol. 65, Pp. 131-145.