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# **Environmental Condition of the City of Ishim** as a Quality of Life Indicator

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#### **Abstract**

**Objectives:** The goal of this study is an overall assessment of natural resources potential and environmental "health" of the city of Ishim according to the indicating characteristics of small mammals. Methods/Statistical Analysis: The assessment of natural resources potential was made by means of biological monitoring with the use of species biodiversity and cenosis stability indicators. The animals were collected by means of non-selective non-recoverable capture method. Snap traps were placed in trap lines, the animals were identified by morphological and craniological characteristics. The material was collected near Sinitsino village, which is located on the territory of nature reserve in Ishim district. Findings: Within the anthropogenic impact gradient, significant changes have been indicated. Including statistically significant decrease in the number of small mammal species, a simplification of taxonomic cenosis structure, change of their ecological structure in favor of the increase of the percentage share of eusynanthropes and synanthropes and the decrease of the relative share of anthropophilic and neutral species to the extent of their total extinction in both settlement zones. A consistent decrease of species diversity index and stability of small mammal's community has been indicated all the way from the parkland zone towards the high-rise building area. By means of quality cluster analysis, it has been proven that the zone of city inarable land is differentiated from the parkland zone. Such findings can be explained by the loss of connection with native habitat, the increase of complex influence of urbanization factors, which results in extinction of some neutral and anthropophilic species, a decrease of the number of red-toothed shrews, which take a higher trophic level than other rodents, etc. Application/Improvements: The study has revealed that the essential conditions for the conservation of species biodiversity potential of Ishim include such factors as preservation of greater greenfield areas and protective habitat capacity and a variety of microsites.

Keywords: Biodiversity Potential, Ecology, Environment, Natural Resources, Small Mammals

### 1. Introduction

The city of Ishim (Tyumen region, Russia) falls under the category of medium size (with the population of 65.3 thousand) old cities (founded in 1782) of Western Siberia. The city is located on the Trans-Siberian railroad and a federal-aid highway intersection. In the recent past the city's transport-geographical position gave it a competitive edge for the economic development. However, in the context of modern economy the most important condition for the city's competitive ability and investment attractiveness is availability of human potential and a better quality of life, which determines the vector of the city's strategic development<sup>1</sup>. Planning

of the city's consistent development is based on a complex strategic analysis of resources and development factors, as well as a complex assessment of the environmental health and natural resources potential of the territory, which are integral to the population's quality of life evaluation<sup>2,3</sup>.

The goal of this study is an overall assessment of natural resources potential and environmental "health" of the city of Ishim according to indicating characteristics of small mammals.

Urbanization, a principally new natural phenomenon that causes unprecedented environmental changes, has been attracting the attention of local<sup>4-10</sup> and foreign scientists<sup>11-21</sup> for several decades. As yet, essential tendencies of changes of species diversity of various animal

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phyla have been indicated upon the urbanization gradient and other concurrent factors within the space<sup>9,10,14,15,18–20</sup> and time aspects<sup>11</sup>, features of urbacenosis ecological structure<sup>8</sup>, specific characteristics of intraspecies variability and population structure of predominant species<sup>8,13,22–24</sup>, behavioral adjustment of animals to urbanized environment<sup>8,16</sup>; the conditions contributing to the preservation of urban ecosystem biological diversity have been defined<sup>7,21,25,26</sup>. The most well-studied groups of animals in this regard are birds and arthropods<sup>11,12,18,27</sup>. A lot of studies have focused on the research into middle latitude urbacenosis<sup>11,18</sup>. However, there is a number of specific studies that look into nature zone-based and historic features of urbanization<sup>4–6,28</sup>.

The most popular parameter used to study the impact of urbanization on living systems of supraorganismal level and to make a general assessment of ecological well-being of urbanized territories is species biodiversity<sup>4,7,9,17,19,28,29</sup>, which can be explained by its emergence<sup>30</sup>. This parameter allows one to evaluate changes that occur at the level of cenosis or animal communities – interacting populations of phylogenetically close species of the same or adjacent trophic level, i.e. the intermediate level between populations and biocenosis where regulation and horizontal redistribution of substance flow and energy take place and where interspecies relations, which ultimately limit biodiversity, are formed<sup>30</sup>. Starting with the fundamental study by 31 and methodological works written by his followers from different countries<sup>22,27,29,32–36</sup> such methods as biodiversity index and dominance/ diversity curves have been used in order to analyze species biodiversity. Margalef Diversity Index, Shannon and Simpson Biodiversity Index, Index of Dominance and Evenness are used more often than other methods in order to evaluate biodiversity. A lot of indices and their modifications have been developed so far. They are widely applied for the assessment of inventory alpha and gamma biodiversity, differentiation beta diversity and cenosis stability<sup>6,22,29</sup>. Based on theoretical and empirical research consistent methodological approaches to the interpretation of species biodiversity change have been worked up<sup>27,30-32,35,37</sup>.

The second important parameter characterizing the influence or urbanization is the condition of some species' population (as a rule, these are predominant species, which allows for gathering significant representational material). In addition to solving a fundamental problem, which is the research of population homeostasis mechanism in

the anthropogenically changed environment, an applied problem of quasi natural environment quality assessment can often be solved alongside. In this case the best gauge of population development stability (population homeorhesis) and of "environmental health" is fluctuating asymmetry of bilateral morphological characteristics<sup>38–40</sup>. In order to assess population homeorhesis of small mammals cranial nonmetric traits are used. These traits are called phenes; they are oligogenic in nature and show a high level of heritability. Methodological foundation for the use of nonmetric threshold characters for the specification of epigenetic processes within small mammals populations and for the indirect specification of genetic population structure was laid by the English genetic scientists of the 1960s41-47, was further developed in the works of local scientists<sup>38,48,49</sup> and has been applied by scientists in different countries<sup>50–52</sup>. A direct connection between the level of fluctuating asymmetry and ecological stress has been indicated in many (but not all) research studies (which can be explained by a high level of buffering in epigenetic system of a population and a lack of potential confounders)<sup>23,24,37-39</sup>. According to developmental biologists<sup>53</sup>, even a slight lack of understanding of the mechanism of fluctuating asymmetry display caused by an incomplete study of regulatory mechanisms of genotype realization cannot hinder the use of fluctuating asymmetry showings in empirical studies.

One of the advantages of some foreign studies is the development and application of intravital study methods of small mammals, which, however, have some limitations when it comes to the diagnostics of animals' species identity<sup>54,55</sup>.

The results of the majority of research studies focused on the influence of urbanization on biodiversity testify to a tendency for a decline in species diversity and evenness along urbanization gradient both in terms of time and location due to predominant reproduction of some synanthropic and ecologically flexible species and "disappearance" of some species which are intolerant of humans14,18,19,28. At the same time, not all research studies show a valid correlation between urbanization and biodiversity decline<sup>11</sup>. Some studies show that the maximum level of biodiversity is observed in moderate urbanization zones characterized by a high level of habitat mosaicism and vegetation variety due to introduced species and artificial landscape compositions subject to preservation of relations between certain biotopes and a connection between urbanized territories and natural

habitats<sup>15,20,25</sup> empirically showed that the identified "decline of biodiversity" along the gradient of human footprint can be caused on the one hand by an undercount of real biotopical diversity, since experimental and control grounds for the observance of the principle of "all other factors being equal" are formed, as a rule, in similar biotopes; and, on the other hand, can result from an insufficient amount of sampling efforts, since the probability of finding species reduces considerably due to their confinedness to the preserved "fragments" of appropriate habitats and their small numbers.

Having researched the consistency of teriocomplexes in urbanized territories, located along Yamalo-Tashkent transect, and his co-authors4-6,28 noted a correlation between the level of biodiversity and the degree of urbanization of the territory, city-planning details of populated localities and their nature and historic features, thus actualizing the study of urbacenosis in different cities in the context of applied aspects of biodiversity preservation and consistent development of various territories 12,17,26.

All the foregoing reasons prove the relevance and newness of the present study due to the combination of methods that allow scientists to evaluate the impact of urbanization at population and cenotic levels of organization. The materials of the present work can serve as a foundation for further monitoring and surveillance studies of the quality of the environment in the city of Ishim as well as in the system of municipal administration of the urban district of Ishim while planning and reconstructing urban development, creating and reconstructing the system of landscaped areas and organizing ecological awareness-building events, which makes this study useful and practically relevant.

# 2. Materials and Methods of Research

The assessment of natural-resources potential was made by means of biological monitoring with the use of species biodiversity and cenosis stability indicators (Table 1). An indicator group included small mammals that met all the indicator species requirements. The animals were collected by means of non-selective non-recoverable capture method. Snap traps were placed in trap lines, the animals were identified by morphological and craniological characteristics<sup>50</sup>. The material was collected in June -

August, 1997 - 2011. Control studies were conducted in the vicinity of Sinitsino village, Ishim district, which is located within 16 kilometers from the city of Ishim on the territory of a relict "Sinitsino Pinewood" nature reserve<sup>49</sup>. Within the city limits animals were collected in different structural-functional zones: 1 - zone of highrise developments; 2 - private residential zones; 3 - city inarable land zone (waste grounds, city dumps, gardens, mini-parks, riverbanks); 4 - parkland zones<sup>28,56</sup>. An integrated point system of anthropogenic load was worked up for every zone according to the following criteria: noise pollution, traffic load, soil degradation, vegetation mantle degradation, littering, food waste deposits, gas contamination (dust, soot), disturbance factor (humans, dogs, building sites). Every factor was evaluated according to a 3-point system (from 0 to 3 points, where 0 means absence of influence, 3 points - maximum influence). An average score was defined by means of summing up the points received for every factor. Vegetation of all the studied zones was represented by artificial plantations of similar species composition, with the exception of anthropogenically transformed phytocenosis, formed on the basis of natural vegetation specific to parkland zones ("Birch Grove" parkland, riverain deciduous forest strip along Ishim River, which should be referred to the city inarable land zone).

In total 2857 trapdays were registered. 554 animals were collected, including: in the high-rise development zone - 235 trapdays and 31 animal units, in the zone of private residence - 246 trapdays and 33 animal units; in the zone of city inarable land - 289 trapdays and 43 animal units; in the parkland zone - 1124 trapdays and 199 animal units; in control - 973 trapdays and 248 animal units.

Small mammals species composition and species abundance were determined within every zone. Biodiversity index and cenosis stability level were calculated; dominance/diversity curves were plotted (species significance) that described alpha-biodiversity of habitats<sup>27,28,31,32,56,57</sup>. Using Statistica (Version 6) computer program Spearman's rank correlation coefficient between the score of anthropogenic impact on the habitat on the one hand and a number of species in cenosis, biodiversity index and cenosis stability on the other hand. Based on the Jaccard faunistic comparative index a quality cluster analysis of samples from different structural-functional zones was performed according to species composition of small mammals; thus, beta-diversity was assessed<sup>25,58,59</sup>.

**Table 1.** Change of species biodiversity and small mammals community stability index upon urbanization gradient

Degree of urbanization	Functional zones				
	1	2	3	4	
Species biodiversity and sustainability index	High-rise development area	Private residential area	Uninhabited area	Woodland park	Pine forest
Relative abundance	13.2	13.4	14.9	17.7	22.5
(individual / 100 traps/ day)					
Index of species richness (R)	0.47	1.21	1.57	3.98	10.3
Shannon index of species diversity (H)	0.15	1.14	0.89	2.17	1.89
Simpson's diversity index (D)	0.04	0.50	0.43	0.70	0.83
Index of polydominance (P)	1.05	2.10	1.76	3.41	6.78
Simpson index of dominance (C)	0.96	0.50	0.57	0.30	0.18
Resistant sustainability of community (Ur)	0.50	2.68	1.87	1.58	1.18
Elastic sustainability of community (Uu)	0.11	0.94	0.88	5.59	19.82
General sustainability of community (U)	0.61	3.62	2.75	7.17	21.0

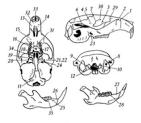
Based on the methods of phenetic analysis<sup>29,33,38,48,50</sup> air-land environmental "health" was evaluated. In order

to do this evaluation development stability indices integral coefficients of fluctuating asymmetry of binary nonmetric cranial traits (phenes) – were used both in experimental and control samples *Clethrionomys rutilus*. The study of phene possession was carried out: possession of 35 phenes by 103 animal units C. rutilus (45 animal units from the experimental sampling group and 57 from the control group); 13 phenes by 163 animal units S. araneus (86 animal units from the experimental sampling group and 77 animal units from the control sampling group (Figure 1)<sup>29,38</sup>. Representative experimental sampling was formed from the animals collected in different structural-functional city zones. An average number of asymmetrically manifested traits per animal unit was calculated as an integral coefficient of qualitative character asymmetry (Number of Asymmetric Traits -NAT): NAT =  $\sum Ai$ , where  $A_i$  – a number of asymmetric

traits manifestation i (number of animal units, asymmetrical according to trait i; n – number of samples; k – number of traits. The received NAT value was compared to the environmental quality index in points according to the integral animal development stability index<sup>29</sup>.

# 3. Research Results and their Evaluation

Different structural-functional zones of the city of Ishim form the following line leading toward the increase of



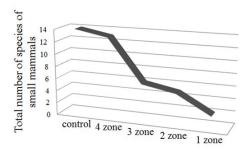


A 1 – antorbital fenestra (Foramen praeorbitale) doubled (FPodu); 2 – frontonasal suture (Sutura nasofrontalis) convex (SNf2); 3 – foramen ethmoidale (Foramen ethmoidale) (Foramen ethmoidale) (Fedu); 4 – temporal foramen (Foramen temporale) doubled (FFidu); 5 – temporal foramen (Foramen ethmoidale); 7 – squamosal orbitalis (Foramen squamosis orbitalis) presence (FSq0); 8 – Senestra mastoid (Fenestra mastoidae) presence (FEdis); 9 – occipital foramen (Foramen corpitalis) single (FOcsi); 10 – superior condyloid foramen (Foramen praemasillare ventralis) absence (FPm(-)); 11 – ventral premaxillary foramen (Foramen praemasillare) spensence (FEdis); 12 – lateral hypoglossus foramen (Foramen praemasillare) presence (FEdis); 13 – ventral submaxillary foramen (Foramen praemasillare ventralis) absence (FPm(-)); 14 – ventral premaxillary foramen (Foramen praemasillare) presence (FFlai); 15 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatains ovally posterior (Furamen (Foramen margina) posterior (Fell); 17 – posterior palatal marging (Magro palatains) posterior (Fell); 17 – posterior palatains ovally posterior (Furamen); 20 – accessory validation of posterior palatains ovally posterior (Fell); 18 – venes (Fell); 19 – postantial posterior (Fell); 19 – postantial

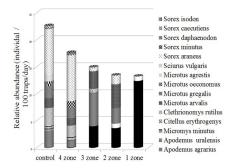
**Figure 1.** Nonmetric cranial traits phene location: A – C. rutilus; B – S. araneus<sup>24,55</sup>. Note: Unitary traits were not taken into consideration while calculating asymmetry coefficient.

anthropogenic impact: control (1 point) < parkland zone (8 points) < city inarable land (19 points) < private residence zone (22 points) < high-rise development zone (27 points).

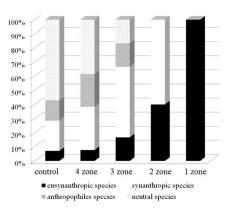
13 species of small mammals of Rodentia and Insectivora order were detected in the territory of Ishim city. A maximum number of species (13) were collected in the territory of a large parkland called "Public Park" 72 ha in area, located in the south-west part of Ishim suburbs. This parkland has a connection with natural landscapes<sup>60</sup>. A minimal number of species (2) were collected in the high-rise development zone. 5 and 6 species were detected in the zone of private residence and the zone of city inarable land accordingly. The following were detected upon anthropogenic impact gradient: a statistically significant decrease of the number of small mammals species (R = -0.82, with p<0.001) (Figure 2), simplification of taxonomic structure of the community (Figure 3), a change of ecological structure of the community in favor of the increase of eusynanthropes and synanthropes' shareand the decrease of the ratio of anthropophilic and neutral species to the extent of their complete extinction in both residential zones (Figure 4).



**Figure 2.** Change of the number of small mammals species upon urbanization gradient.

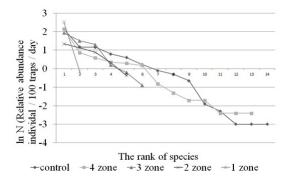


**Figure 3.** Taxonomical composition and abundance (units/100 trapdays) of small mammals in different structural-functional zones of Ishim.

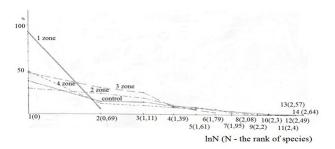


**Figure 4.** Change of ecological structure of small mammals communities upon urbanization gradient.

On the whole, the level of species biodiversity is not high, which is not uncommon for temperate zone ecosystems. Thus, the maximum value of Shannon biodiversity index, which is widely applied in biodiversity research, does not reach 50% from the average maximum empirical value of the indicator described in literature (Figures 4 and 5)27,29. The highest level of biodiversity of small mammals with a minimal dominance of some species was indicated in the parkland zone community, which is quite similar to the natural control community (Figure 4, Table 1). The dominance/diversity curve (species significance) of the high-rise development zone demonstrates a minimal level of biodiversity (it cuts off at the second rank) and a maximum dominance of one specie - Mus musculus (Figures 5 and 6). Different types of curves of species' significance for the high-rise development zone community (zone 1) are represented by straight lines, which conforms with Motomura's geometric distribution model<sup>36</sup>, typical of habitats with a small amount of species or communities at a very early stage of succession (Figures 5 and 6).



**Figure 5.** Dominance/diversity curves of small mammals in communities of different structural-functional zones.



**Figure 6.** Small mammals species significance curve in communities of different structural-functional zones: X axis – natural logarithm (ln) of the species' rank; Y axis – relative abundance (%).

The model is based on a hypothesis of predominant capture of an ecological niche. According to this hypothesis ecological niches of different species in a cenosis do not overlap<sup>27,34</sup>.

The curves of species significance in communities of small mammals from the other structural-functional zones and from the control group conform to MacArthur's "broken stick model"34, which assumes that every niche is divided into random adjacent but not overlapping areas. Such distribution is typical of communities with intensive interspecies competition<sup>27,32</sup>, which, in this case, can be explained by a limited land capacity. The curve of species significance of parkland zone communities demonstrates a greater evenness of some species. At the same time, an abundance of some species ranked along the row of relative abundance in the parkland zone community changes more drastically than in the control group, which testifies to a lower resource capacity of the habitat. Even a lesser capacity is typical of the city inarable land zone and the private residence zone. For these the curve of species significance cuts off at ranks 6 and 5 accordingly, and demonstrates drastic changes of the abundance of some species (Figures 5 and 6).

As the anthropogenic impact on habitats increases in the zones between parkland and high-rise developments, the following exponents suffer a statistically significant decline: index of polydominance (R=-0,9; p<0,05), resistance index (R=-0,9; p<0,05) and general community sustainability (R=-0,9; p<0,05) while Simpson dominance index increases (R=0,9; p<0,05) (Table 1).

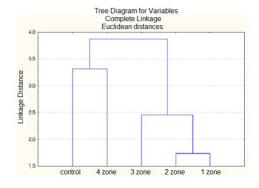
The identified inverse proportion between the level of urbagenic impact and species diversity of small mammals is consistent with the data of other authors who studied animal communities in different structural-functional city zones of similar biotopes<sup>4,14,18,20,29</sup>.

On the whole, the decrease of species biodiversity of small mammals (H - 14.5 times, D - 17.5 times) towards the increase anthropogenic impact leads to a substantial decrease of general cenosis stability (U - 50.8 times) (Table 2).

A faunistic comparative analysis of small mammals community from different structural-functional zones by means of Jaccard's index (Jj) showed a high level of similarity between teriocenosis of the parkland zone and the control group, and a high level of similarity between teriocenosis of the high-rise development areas and the private residence zone (Table 2). A similar tendency can be observed on a dendrogram based on the method of Euclidean distance between samples (Figure 7). The samples from natural habitats and parkland areas on the one hand and two residential zones on the other hand, make up two separate clusters. The sample from the city inarable land zone takes an intermediate position, but according to the complete link method it is linked to the residential zone cluster.

Table 2. Matrix of faunistic similarity of small mammals communities from different structural-functional zones of the city of Ishim (Jaccard's Index Jj)

	1 zone	2 zone	3 zone	4 zone	control	
1 zone	-	0.400	0.14	0	0.060	
2 zone	0.400	-	0.375	0.270	0.250	
3 zone	0.140	0.375	-	0.385	0.310	
4 zone	0	0.270	0.385	-	0.440	
control	0.060	0.250	0.310	0.440	-	



**Figure 7.** Euclidean distance between samples from different structural-functional zones of the city of Ishim according to species composition of small mammals.

Thus, the zone of city inarable land, including public gardens, parks and tree-belt areas, is well-differentiated from the parkland zone. This can be explained by the loss of connection with natural habitats; the increase of complex influence of urbanization factors that determine the decrease of species abundance in the community due to the disappearance of some neutral and anthropophilic species; by the decrease of the number of red-toothed shrews which take a higher trophic level compared to rodents, and, therefore, are more susceptible to contaminants and pollutants; and by the decrease of resource capacity of habitats as a result of their transformation leading to soil and vegetation degradation.

The last point can be confirmed by the example of "Birch Grove" parkland which is regarded as a special protection national territory. This medium size parkland (14.9 ha) is located within the city infrastructure<sup>60</sup>. Excessive recreational impact along with a small area of the parkland and complex influence of other urbanization factors have led to the degradation of soil (soil packing, water-air regulation disturbance) and grass layer, represented byvegetation which has led to low species diversity of the small mammals community of the "Birch Grove" parkland which is characterized by bidominant anthropogenically adjusted community of synanthropes - Apodemus agrarius, and eusynanthropes - Mus musculus<sup>61</sup>. This parkland has been included with the city inarble land zone according to the dominance pattern in the community of small mammals (where only eusynanthropes and synanthropes are presented).

The analysis that has been carried out makes it possible to think that the main factors that support species diversity of small mammals in the territory of Ishim are the connection with natural landscaped areas, large greenfield areas with a well-developed grass layer, which

provides feeding and protective capacity for the habitat, and with a diversity of microbiotopes. The analysis makes it possible to assume that the further decrease of parkland zone area will endanger biodiversity leading to its loss and, eventually, to the loss of natural resource potential of the territory.

According to the integrated development stability index the condition of homeorhesisin the experiment and control populationcan be evaluated as rather stable, the condition of air-land environment - as "clean", and "environmental health" as good (Table 3).

This can be explained by the absence of large-scale industrial production and significant stationary sources of air pollution in the city of Ishim<sup>62-67</sup>.

# 4. Conclusions

A considerable decrease of species biodiversity and sustainability of the indicator group of animals small mammals, is observed upon urbanization gradient in the territory of Ishim. The highest level of biodiversity and the highest level of sustainability with the minimal dominance is observed in the parkland zone that takes a large area and is connected with natural landscapes. The decrease of the parkland zone and the loss of its connection with natural landscapes and natural habitats, as well as the increase of anthropogenic impact resulting from urban planning activities, may endanger biodiversity leading to its loss and, eventually, to the loss of natural resource potential of the territory.

Table 3. Quality of air-land environment assessment of the city of Ishim according to the integral coefficient of fluctuating asymmetry of nonmetric cranial traits of small mammals

	Integral Coefficient of Fluctuating Asymmetry Based on a Point System <sup>30</sup>						
	< 0,35	0,35-0,40	0,40-0,45	0,45-0,50	> 0,50		
Degree	1	2	3	4	5		
	clean	relatively clean	rather polluted	polluted	extremely polluted		
C. rutilus							
Experiment(parkland zone)	0.202						
	"Clean", degree of quality of air-land environment - 1						
Control	0.203						
	"Clean", degree of quality of air-land environment - 1						
S. araneus							
Experiment (parkland zone)	0.017						
	"Clean", degree of quality of air-land environment - 1						
Control	0.056						
	"Clean", degree of quality of air-land environment - 1						

- According to the integrated development stability index of the condition of the population of *C. rutilus* and *S. araneus*, the "health" of air-land environment of the city of Ishim can be evaluated as good, which can serve as a prerequisite to forming high life quality of Ishim population.
- In order to preserve natural resources potential
  of the city of Ishim, it is necessary to work up and
  implement a plan of actions targeted at preservation
  and development of the city landscaped areas.

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