# Screening of the state of urban ecosystem with the use of bioindication method (on the example of Kazan city)

**E A Minakova[1], A P Shlychkov[2] and A V Arinina[1]**

[1]Institute of Fundamental Medicine and Biology, Kazan Federal University, Kremlevskay str, 18, 420008, Kazan, Russia
[2] Institute of Ecology and Environmental Sciences of the Republic of Tatarstan, Kremlevskay str, 18, 420097, Kazan, Russia
e-mail: ekologyhel@mail.ru

**Abstract**. The urban environment is a complex of natural, natural-anthropogenic and socio-economic factors that exert a large and diverse impact on urban residents. In addition to traditional environmental monitoring, we propose to use a new bioindication method based on the evaluation of morphological changes in the leaves of *Betula pendula* Roth by fluctuating asymmetry (FA) to assess the quality of recreational areas. Such screening for the purpose of assessing of the environment state is very informative, since the bioindication assessment is an integral characteristic of the quality of the environment which is under the influence of all the abundance of chemical, physical and other factors. The two-sided symmetry of a leaf was calculated on the sites in the middle of the park zone, on the border of the park and on a roadside strip. The results of the study showed a connection between the FA values and the distance to the highway, and also revealed the absence of significant differences in FA indicators at the surveyed sites, which may indicate insufficient sizes of recreational areas and their insufficient potential to contribute to improving the quality of the environment.

## 1. Introduction

The urbanized environment, especially a comfortable urban environment, the developed infrastructure, social and economic benefits bear in themselves the mass of the environmental problems which are now extremely actual. Atmospheric air of the modern cities contains hundreds of organic and inorganic substances of various chemical classes arriving from numerous sources, as a rule, of anthropogenous character.

Biological monitoring allows to estimate integrally a state of environment and to carry out screening of anthropogenous impact on live objects. Perspective approach to biomonitoring of difficult natural and anthropogenous systems is the assessment of a condition of populations from an ontogenetic point of view on the basis of a morphogenetic monitoring method, or an assessment of the level of stability of live organisms development.

Intensive studying of the phenomena of asymmetry devoted to the use of the fluctuating asymmetry phenomenon at environmental monitoring of natural populations such as plant populations has begun relatively recently and is marked by works of both foreign and Russian researchers [1-8]. Rather large number of works is devoted to an assessment of stability of development of organisms in nature [9-11], as well as to exert influence on stability of development of climatic factors [12]. Other application of the approach is its use for monitoring of health of the environment in the protected natural territories or for regional monitoring [13]. In recent years, there have been many researches devoted to

the use of a FA phenomenon in assessment of anthropogenous impact in urban, recreational environment and in vicinities of industrial facilities.

## 2. Material and methods

Multicomponent influence complicates an the assessment of anthropogenous impact, therefore for these purposes the bioindication methods give a chance of the integrated characterization of quality of the environment which is under the influence of all variety of physical, chemical and other factors. Biological monitoring allows to estimate integrally a state of environment and to carry out screening of the anthropogenous impact on living objects.

Perspective approach to difficult natural and anthropogenous systems biomonitoring is the assessment of the populations conditions from the ontogenetic point of view on the basis of the morphogenetic monitoring method or an assessment of living organisms development stability level.

The plant is an important object for characterizing the state of the natural environment. They are the main producers; plants are sensitive objects allowing to evaluate the whole complex of impacts characteristic of the given territory; they lead an attached way of life, the state of their organism reflects the state of a particular local habitat; the use of plants consists of the accessibility and simplicity of collecting material for research. Now the methods of bioindication which are most often put into practice consider morphological changes of the higher plants. The main approach to an assessment of morphological changes, owing to violations of a homeostasis of development, is morphogenetic which basis is the characteristic of stability of development, and one of the main morphological criteria is the size of the fluctuating asymmetry. The Fluctuating Asymmetry (FA) refers to small, not directed (random) deviations from bilateral symmetry of organisms or their parts. The basis of this research is the method of an environment quality assessment [14]. FA measures small non-directional deviations from the usually strict bilateral symmetry and characterizes the morphogenetic homeostasis or stability as a result of the imperfections in the growth processes. The value of FA gives the characteristic of the morphogenetic homeostasis or stability of development and is defined as a result of ontogenetic processes imperfection and represents the insignificant, not directed deviations from strict bilateral symmetry and can be characterized as one of the most usual and available display of development random variability. At the normal state of environment its level is minimal, at the increasing negative impact it increases that leads to an increase of asymmetry [15].

The birch tree (Betula pendula Roth.), the Birch family Betulaceae, was chosen as the research object for definition of development stability extent, the Birch family Betulaceae. The research data was collected in years 2014 – 2016. Seven platforms were put in place in the recreational territories of Kazan (figure 1). On each platform two sampling points were targeted:

- in a park zone
- on the border of a park and a roadside strip at a distance of 10 to 30 m from a zone of highways influence.

In total, 42 selections were collected and analysed during the research in recreational zones of Kazan from 2014 to 2016 yrs and 42000 measurements were executed.

For an assessment of an indicator of the fluctuating asymmetry they used a leaf as the body exhibiting bilateral symmetry. Leaves in quantity of 10 pieces from 10 trees in each point were gathered till a full stop of leaves growth (since the middle of August), from the short shoots evenly on all perimeter in the lower part of tree crown on the trees of generative age growing in identical light conditions. Parameters of the left and right half of a leaf plate were measured. To receive statistically reliable data 100 leaves were gathered on each test platform. For each leaf, on both left and right side, values of five measurements (figure 2) are as follows:

1 – width of the left and right halves of a leaf;
2 – length of a vein of the second order, the second from the leaf basis;
3 – distance between the bases of the first and second veins of the second order;
4 – distance between the ends of the same veins;
5 – corner between the midvein and the second from the leaf basis a vein of the second order

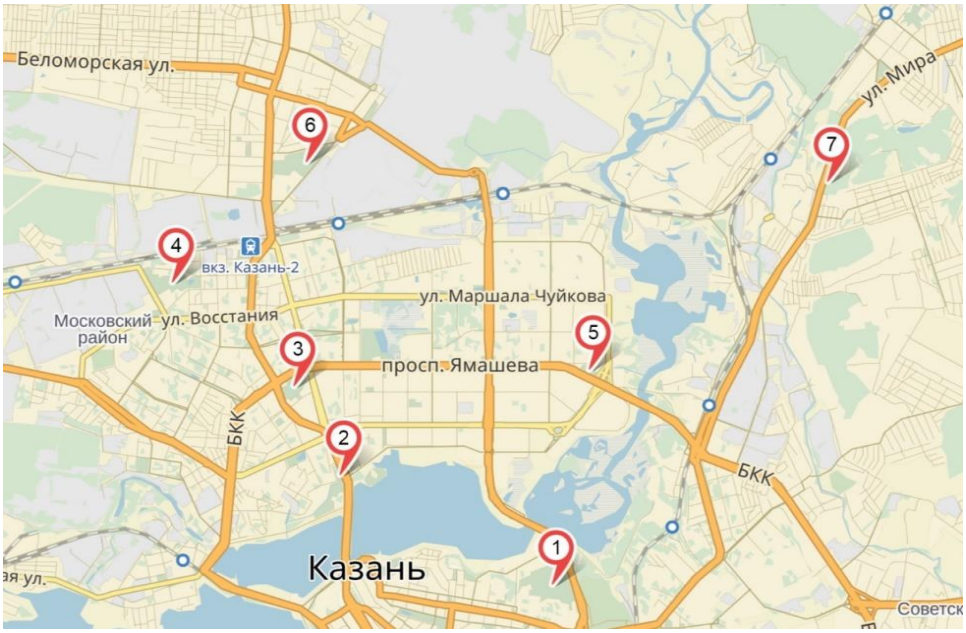


**Figure 1.** Platforms of selection of material in Kazan: 1. Gorky Park - Vakhitovsky district; 2. Kyrlay park - Moskovsky district; 3. Recreation Center Park of Chemists - Moskovsky district; 4. Uritsky Park - Moskovsky district; 5. Continent Park - Novo-Savinovsky district; 6. Krylja Sovetov Park - Aviastroitelny district; 7. Derbyshki Birchwood - Sovetsky district.

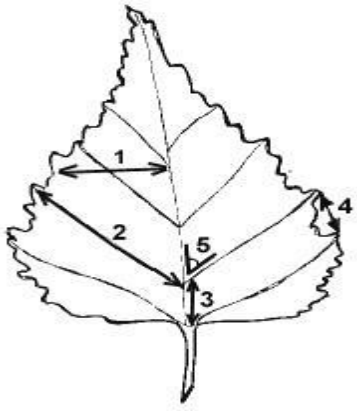


**Figure 2.** The scheme of measurements of a birch leaf used for an assessment of size of the fluctuating asymmetry.

The size of the fluctuating asymmetry of plants was estimated by means of an integrated indicator that is the value of average relative deviations per sign (a ratio of differences to the sum of measured values on the left side and on the right side of a leaf, referred to the number of signs) [16]:

$$FA = ABS(L - R)(L + R)^{-1}$$

where: FA – an integrated indicator of the fluctuating asymmetry;
ABS – an absolute value;
L – sign value on the left side of a leaf;
R – sign value on the right side of a leaf.

Statistical processing was carried out on the basis of the Microsoft Office Excel program. For detection of statistical distinctions between indicator sizes of the fluctuating asymmetry in paired comparison Student's t-criterion was used. Distinctions higher than 95% are considered statistically significant. In some cases, methods of nonparametric statistics, in particular Spearman's rank correlation coefficient, were applied.

The scale offered by V. M. Zakharov and coauthors for a birch was applied to an assessment of quality of the environment (table 1).

**Table 1.** Scale of an assessment of quality of the environment in terms of developmental stability indicators of a birch (*Betula pendula Roth*).

| Score | Quality of the environment | Value of the developmental stability indicator |
|---|---|---|
| 1 | Conditionally normal | < 0.040 |
| 2 | Initial (insignificant) deviations | 0.040–0.044 |
| 3 | Average level of abnormalities | 0.045–0.049 |
| 4 | Significant (significant) deviations | 0.050–0.054 |
| 5 | Critical condition | > 0.054 |

## 3. Results and discussion

The results stated in the real work are a part of complex territorial bioecological researches on the territory of the Republic of Tatarstan [17, 18] conducted at the Department of Bioecology, Hygiene and Public Health of the Kazan Federal University since 2012.

Results of the taken measurements and FA calculated values are shown in figure 3. On a rating scale of an assessment of quality of the environment, by the indicators of violation of development stability of Betula pendula Roth. on all relevant platforms, the FA level exceeding the size of conditional norm is shown (> 0.04) that testifies to a critical condition of the environment in the studied recreational territories of Kazan.

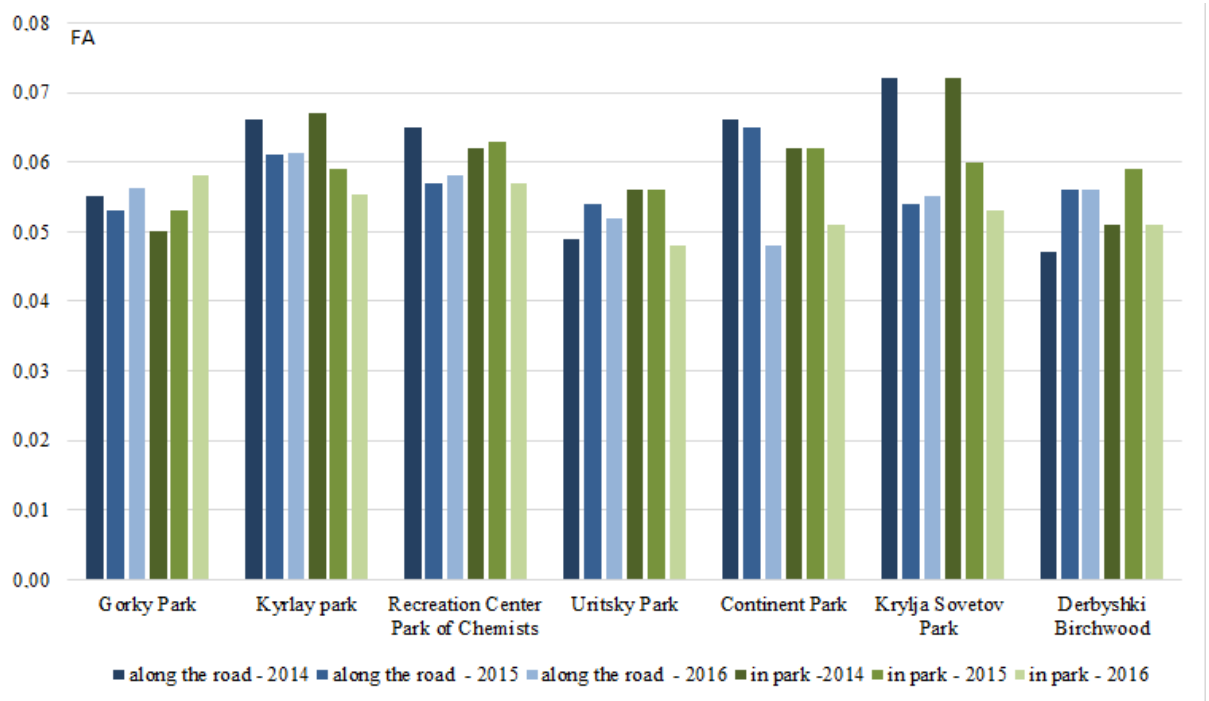


**Figure 3.** Dynamics of the FA index in parks of Kazan (2014 – 2016 years).

By comparing the FA indexes in inside-park and roadside platforms within one site found no significant differences in the FA indicators, which can testify to an insufficient sizes of Kazan city recreational zones and as a result of this it can testify to an inadequate capacity of the recreationarea to promote improvement of environmental quality.

The surveyed recreation areas of Kazan were divided into two groups in compliance with the scale of an assessment of environment (table 1, figure 4):

- territories with critical condition of environment (Park of Chemists, Continent Park, Kyrlay Park, Krylja Sovetov Park) – FA > 0.055;
- territories with essential deviations of quality of environment (Gorky Park, Uritsky Park, the Birchwood square) – FA < 0.055.

In general, uneven distribution of the FA index across the territory of the city was observed during research, and on the most part of its territory the environmental quality didn't meet conditional standard and was characterized as critical.

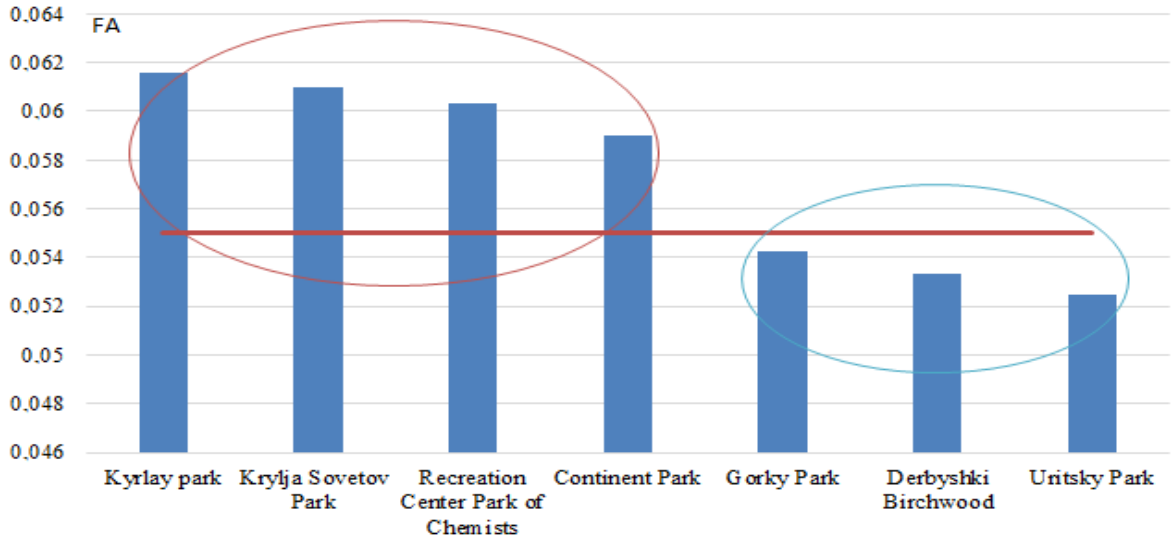


**Figure 4**. Average values of FA in the studied parks for 2014-2016 years.

During the conducted research we found a link between values of FA and a distance to the highway (figure 5). It shows that at a distance of 30 or more meters from the highway the quality of the environment is already characterized as conditionally normal.

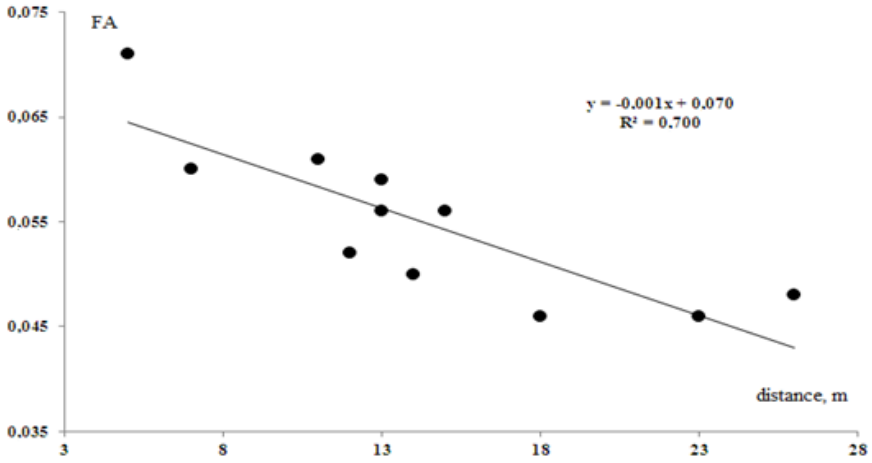


**Figure 5.** Dependence of size FA on the studied platforms from distance to the highway, m.

The coefficient of correlation is significant at the level α = 0.05. The factor of S defines 70% of dispersion of FA. For the analyzed $R^2 > 0.5$ it testifies to the noticeable force of communication between sizes FA and S.

Received average values of FA indicators on platforms for the entire period of supervision and the trend of change of the FA index (figure 6) is constructed. The analysis of dynamics of the average years given in a 2014 – 2016 retrospective on platforms in parks and on roadside sites allowed to reveal a trend of the FA index change towards improvement of a state of the environment (the FA index <0.055). It revealed that during the considered period of 2014 – 2016 yrs. the average values of the integral FA index in Kazan exceeded the value of the conventional norm (FA> 0.044).

During the follow-up period, the trend of decreasing FA values for Kazan city from V point (critical quality of the environment, FA > 0.054) to IV and III points (significant and average deviations from the norm) was observed on the scale of environmental quality assessment, which allows to speak about self-healing of birch pellucid (*Betula pendula Roth*.).

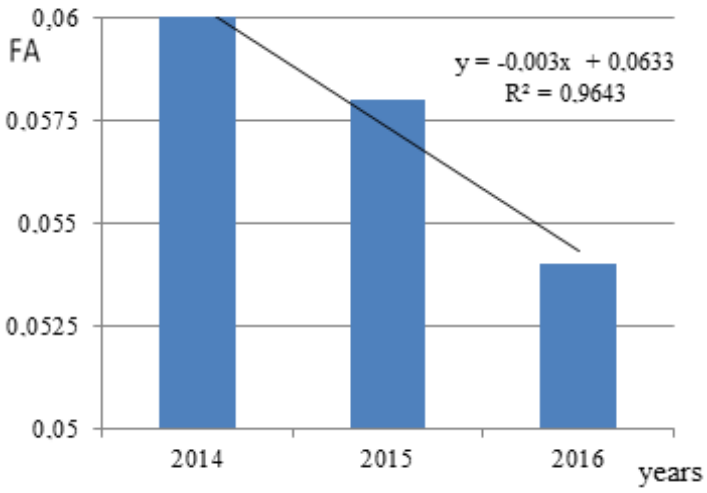


**Figure 6.** Average values of FA to Kazan (in parks and along roads).

Considering the reported results and materials of research on the size of FA of birch leavesin other cities of Russia showed that the FA values received in Kazan are comparable to the results obtainedin other cities of the Russian Federation: in Togliatti the indicator of FA varies from 0.035 to 0.056 [19], in Stavropol 0.025-0.056 [20], in Khanty-Mansiysk 0.053-0.057 [21], in Ufa 0.053 – 0.059 [22], in Barnaul 0.046 – 0.084 [23], in Yakutia in an urban environment 0.042-0.056 [24].

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