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APPROBATION OF ECOSYSTEM STANDARDIZATION CRITERIA ACCORDING TO PHYTOINDICATION COMPONENT

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Safonov A. I. **Approbation of ecosystem standardization criteria according to phytoindication component. –** The criteria for establishing the degree of normality are indices of indicational botanical expertise: informative transformation of plant indicators' structure, the scope of their ecological range and implementation of strategies for new types of adaptive scenarios.

Key words: indicational botanical expertise, transformation of plant indicators' structure.

Introduction

Ecosystem standardization is part of applied direction in ecology – standardization of level of anthropogenic pressure on the environment.

Introducing ecosystem standardization is based on complex integral indices of harmfulness. These indices individually or in combination reflect the degree of resistance or equilibrium of ecosystems of different scales.

According to any parameter reflecting reproductive biology or relationships between a plant and environment, the species form continuum that is reduced to the discrete types because of pragmatic reasons. Continuum of species strategy (behavior) reflects their relationships to the level of resource supply, biotic factors and disturbances [1, 4, 5]. The last index is basic for analysis of disturbed habitats on the territory of Donbass [11].

Different species adapts to the same environmental factor using different sets of physiological and structural modes. The greater number of such modes, the more successfully species can get over environment resistance [3, 10]. When monitoring landscape changes, the visual landscape should also be considered. This pertains to the information function of ecosystems and landscapes that refers to environmental structure and its function for satisfying needs [6, 12].

The program is ambitious. Essential elements are: to consider temporal and spatial interactions, to involve an adapted management of all ecosystems, an integrative monitoring of changes in ecosystem structures and functions, the interdisciplinary research with a broad perspective and a close cooperation with stakeholders and decision makers, cooperative decision-making including scientists, landscape planners, politicians and the local and regional population, to include integrative ecological perspectives in the spatial and temporal planning procedures, the attempt to carry out appropriate decentralized decision-making and, last not least, to implement all regions with various population densities into a sustainable ecosystem management [7, 8, 10].

The working hypothesis of the article is as follows: transformation of ecosystem in the direction of imbalance results in visible disorders on the structural levels of the organization of plant organisms.

The aim of the work is to prove correlation between the level of transformation of ecosystems and the extent of phytoindication informativity in monitoring research in industrial region.

Material and methods

When justifying the quantitative estimates of ecosystem stability resistance of separate components of natural and technogenic systems were considered. While studying the qualitative state of plant landscape elements the principle of threshold actions were used [5, 6, 9].

The definition of stability of natural ecosystems is closely connected with phytoindication indices. We considered indices of weed plants structure as informative criteria of ecosystems resistance towards anthropogenic pressure. The research was conducted in the Donetsk region (Ukraine). The materials were being collected from 2001 till 2012. The test sites were laid in node localization of the monitoring network. To obtain stationary data we chose 30 points where the level of industrial pollution is the highest in the region, 10 points that were the most affected by human influence (landscape transformation, agricultural use) and 5 control points – the sites corresponding to the background environmental monitoring – areas of natural reserve fund of Ukraine. Principles of laying the monitoring grid were in conformance with the literature [8, 12], the regional environmental terrain, topography, soil horizon and the type of plant communities being taken in consideration. Phytoindiacation experiment was organized on out-ecological level. In accordance with the procedures accepted in scientific literature, the structural changes in plant organisms under high human pressure and toxic pollution were taken into account [9, 11].

The material is structurally presented by the following scheme:

- peculiarities of the environment state in industrial regions (edaphotopes and superficial pollution of biogeocenosis);
- ways of determining of plants' reaction to the action of factors of technogenic stress;
- indication trends: asymmetry of plants texture, structural transformations, abnormalities, functional criteria;
- strategies of species' survival under conditions of industrial pollution, ways of realization of vital positions of species of plants and signs of functional adaptation in the anthropogenically transformed environment.

Berteroa incana (L.) DC., *Capsella bursa-pastoris* (L.) Medik., *Echium vulgare* L., *Polygonum aviculare* L., *Euphorbia seguieriana* Neck., *Kochia laniflora* (S. G. Gmel.) Borb., *Agrostis stolonifera* L., *Elytrigia repens* (L.) Nevski), *Artemisia absinthium* L., *Anthoxanthum odoratum* L., *Artemisia vulgaris* L., *Convolvulus arvensis* L., *Digitalis purpurea* L., *Eupatorium cannabinum* L., *Chenopodium album* L., *Cirsium arvense* (L.) Scop., *Daucus carota* L., *Calamagrostis epigeios* (L.) Roth, *Lactuca tatarica* (L.) C. A. Mey., *Amaranthus retroflexus* L., *Dactylis glomerata* L., *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Deschampsia caespitosa* (L.) Beauv., *Galium mollugo* L., *Cynoglossum officinale* L., *Diplotaxis tenuifolia* (L.) DC., *Arrhenaterum elatius* (L.) J. et C. Presl., *Swida alba* Opiz, *Gnaphalium uliginosum* L., *Cyclachaena xanthiifolia* (Nutt.) Fresen, *Grindelia squarrosa* (Purch) Dunal, *Xanthium albinum* (Widd.) H. Scholz, *Ailanthus altissima* (Mill.) Swingle, *Stenactis annua* Nees, *Reseda lutea* L., *Fallopia convolvulus* (L.) A. Löve, *Rumex crispus* L., *Erucastrum armoracioides* (Czern. ex Turcz.), *Amaranthus albus* L., *Digitaria sanguinalis* (L.) Scop., *Persicaria maculata* (Rafin.) A. & D. Löve, *Oberna behen* (L.) Ikonn., *Salsola australis* R. Br., *Ambrosia artemisiifolia* L. were used as plant-indicators. Most of them are species with wide ecological amplitude and valence, found with equal probability both in experimental and control areas.

This work is implemented in the complex and in the continuation of the previous publication [11].

Results and conclusions

Management decisions taken while organizing proper environmental control of the environment in the Donetsk region requires adequate information on the current state of the natural environment. Plants are a key element in the structure of natural ecosystems, and therefore reflect to a large extent the dynamics and specifics of pollution in different points of observation.

Among classical sciences used in ecological programs botany stands out very well and not without reason. Informative character of the data on the state of plants has been underlined repeatedly in many scientific works [3, 5, 6, 7, 10, 12], but against the background of numerous digital, spatial and neo-analytical methods, elaborations of botanists-ecologists are presented quite superficially or are being ignored undeservedly in manuals and specialized scientific reviews.

In conditions of estimation of monitoring systems in the Donetsk region there are only State Administration of ecoresources and the department of computer systems of monitoring in the Donetsk National Technical University mentioned. Most often the botanical component is not used in investigating ecological state of the region. In such cases they operate only with the amount of omissions, thousands of tons a year, but this information can by no means help to reflect the real picture of ecosystems state and the extent of misbalance in natural systems, especially for such anthropogenically transformed region as the Donetsk region. The purpose of the work is conducting, parallel to the existing technical, an additional botanical and ecological monitoring which is based on the methods of structural phytoindication of metallic pressure in anthropogenically transformed environment. Total indices of paratypical variability of phytoindicators have been obtained, where values from 41 to 60 correspond to inadmissible level of pollution.

In conditions of anthropogenically transformed environment and raised toxic pressure onto natural systems the top priority task was finding out the possibilities and reality of practical introduction of phytoindication methods with the aim of total summary estimation of ecological misbalance in an industrialized region [11].

On preliminary research we have elaborated a project of the method of «The integral phytoindication index of combinative influence of non-specific stress factors». After approbation of this method and for adaptation of scale formation we suggest to increase maximum diapason of the scale from 60 to 100, so that the maximum index (100) corresponded to maximal possible diapasons of steadiness of plants under given ecological conditions. There can be several approaches, directions and criteria of phytoindicational estimation of metallic pressure in anthropogenically transformed environment. The most important is obtaining objective and adapted to a given locality results as well as the possibility of conducting permanent monitoring for replenishment of the database and checking out the obtained conclusions.

It's stated that there are certain reactions of plants to pollution of anthropogenically transformed environment with heavy metals, besides, a complex of methodological modes of structural phytoindication of south-eastern industrial centers of the Donetsk region had been worked out. The most successful and therefore perspective with extrapolation of phytoindication methods turned out to be *Cichorium intybus* L., *Tripleurospermum inodorum* (L.) Sch. Bip., *Plantago major* L. and *Tanacetum vulgare* L. These species are indicator not due to frequency in natural and transformed ecotopes, but due to their morphological plasticity, which is informative under conditions of metallic pressure, mostly of anthropogenical origin.

For providing a 100-mark summary scale by the most informative indices (over 90% probability) we've chosen the following (table):

- the level of pollen defectness;
- indices of trichome diversity, that is complexity of the form and texture of trichomes;
- indices (2) of matrical heterocarpy and heterospermy (for various-seeded forms);
- indices (2) of teratological synchotily and schisochotily;
- index of deformation of terminal floema of leaf of phytoindicators;
- index of abnormality of anastomose net of the leaf of apex formation;
- index of total variability of pollen form (according to determined pollen types);
- index of frequency of deformed or under formed embryo of phytoindicators.

For each of the indices there's an individual additive estimation scale of 10 marks maximum value in regional standards, established experimentally for Donetsk region. The whole diapason of structural ecological changeability of plants has been taken into account.

Provided the use of 10 mentioned parameters, summary index of plants reaction to the action of non-specific stress will be totally equal an integral level and power of stress factors on ecological systems of the territory under analysis. The maximum number of marks with the help of these indices equals 100, the minimum – 10. According to approved methodologies for different research objects we recommend the following conventional scale of estimation of the level of toxic pressure to natural systems (table 1): 10-25 – normal state of ecosystem; 26-35 – admissible, 36-75 – level exceeding normal one, 76-100 – inadmissible level of misbalance in natural systems under analysis.

The inevitable though frequently informal use of expert opinion in modeling, the increasing number of models that incorporate formally expert opinion from a diverse range of experience and stakeholders, arguments for participatory modeling and analytic-deliberative-adaptive approaches to managing complex environmental problems, and an expanding but uneven literature prompt this critical review and analysis [8].

Table 1

Results of phytoindicational monitoring (for 1-2 km zone of each of enterprises)

Enterprise	2001 yr	2005 yr	2006 yr	2007 yr	2012 yr
OJSC «Ilyich Iron and Steel Works of Mariupol»	98,1	98,3	97,2	95,4	95,3
OJSC «Iron and Steel Works of Mariupol 'Azovstal'»	97,3	97,2	96,8	95,3	95,5
Starobeshevo TEPS OJSC «Donbassenergo»	60,0	60,3	60,1	60,6	60,5
Kurakhovo TEPS OJSC «Skhidenergo»	30,5	30,4	30,9	30,2	30,0
Vuglegirsk TEPS OJSC «The State energy generating company «Centrenergo»	28,4	28,4	28,8	29,0	27,5
OJSC «The Zasiadko coal mine»	70,0	70,0	72,5	72,3	71,8
Zooevka TEPS-2 «Skhidenergo»	25,9	24,2	18,4	19,3	18,8
Slovyansk TEPS OJSC «Donbassenergo»	26,7	26,5	25,1	25,1	25,0
OJSC «Iron and Steel Works of Makiyivka»	88,4	88,3	86,0	84,5	80,6
OJSC «Iron and Steel Works of Yenakiyevo»	98,6	98,6	95,1	96,2	94,4
OJSC «Coke and Chemical Works of Avdiyivka»	25,5	25,0	20,6	21,0	21,0
OJSC «Markokhim»	35,5	35,7	39,0	40,1	40,1
OJSC Coalmine «Pivdennodonbasska №1»	32,6	40,0	43,2	43,0	41,1
OJSC «Donetskstal», OJSC Iron and Steel Works of Donetsk»	98,8	98,1	92,1	94,7	92,6
OJSC «Coke and Chemical Works of Yasynuvata»	10,5	10,0	10,3	10,1	10,2
OJSC «Coke and Chemical Works of Yenakiyevo»	79,0	77,0	74,2	75,3	73,9
OJSC «Coke and Chemical Works of Makiyivka», CJSC «Makyivkoks»	75,6	74,1	73,0	72,2	73,7
OJSC «Donetskkoks»	34,0	33,4	33,5	32,9	32,5

Aims are to propose common definitions, identify and categories existing concepts and practice, and provide a frame of reference and guidance for future environmental modeling. The inevitable though frequently informal use of expert opinion in modeling, the increasing number of models that incorporate formally expert opinion from a diverse range of experience and stakeholders, arguments for participatory modeling and analytic-deliberative-adaptive approaches to managing complex environmental problems, and an expanding but uneven literature prompt this critical review and analysis [8]. Aims are to propose common definitions, identify and categories existing concepts and practice, and provide a frame of reference and guidance for future environmental modeling. The extensive literature review and classification conducted demonstrate that a broad and inclusive definition of experts and expert opinion is both required and part of current practice. Thus an expert can be anyone with relevant and extensive or in-depth experience in relation to a topic of interest. The literature review also exposes informal model assumptions and modelers subjectivity, examines in detail the formal uses of expert opinion and expert systems, and critically analyses the main concepts of, and issues arising in, expert elicitation and the modeling of associated uncertainty. It is noted that model scrutiny and use of expert opinion in modeling will benefit from formal, systematic and transparent procedures that include as wide a range of stakeholders as possible. Enhanced awareness and utilisation of expert opinion is required for modeling that meets the informational needs of deliberative fora. These conclusions in no way diminish the importance of conventional science and scientific opinion but recognise the need for a paradigmatic shift from traditional ideals of unbiased and impartial experts towards unbiased processes of expert contestation and a plurality of expertise and eventually models. Priority must be given to the quality of the enquiry for those responsible for environmental management and policy formulation, and this review emphasises the role for science to maintain and enhance the rigour and formality of the information that informs decision making.

The criteria for establishing the degree of normality are indices of indicational botanical expertise: informative transformation of plant indicators' structure, the scope of their ecological range and implementation of strategies for new types of adaptive scenarios.

If you break up the structure of plants into informative blocks, the most informative species of plants in these groups are as follows:

- appearance of the structure of plants, the life form (*Berteroa incana* (L.) DC., *Echium vulgare* L., *Reseda lutea* L.);
- architectonic features of the underground organs (*Capsella bursa-pastoris* (L.) Medik., *Polygonum aviculare* L., *Reseda lutea* L., *Echium vulgare* L.);
- transformation in the root tip terminals (*Capsella bursa-pastoris* (L.) Medik., *Reseda lutea* L., *Echium vulgare* L.);
- variability in shoot formation, inflorescence formation (*Berteroa incana* (L.) DC., *Capsella bursa-pastoris* (L.) Medik., *Reseda lutea* L., *Echium vulgare* L.);
- variability of the conduction system in the stem of plants (*Fallopia convolvulus* (L.) A. Löve, *Rumex crispus* L., *Capsella bursa-pastoris* (L.) Medik.);
- foliage system formation in different formations (*Berteroa incana* (L.) DC., *Digitaria sanguinalis* (L.) Scop., *Persicaria maculata* (Rafin.) A. & D. Löve, *Elytrigia repens* (L.) Nevski, *Reseda lutea* L., *Echium vulgare* L.);
- variation in leaf surface structures (*Berteroa incana* (L.) DC., *Erucastrum armoracioides* (Czern. ex Turcz.), *Amaranthus albus* L., *Reseda lutea* L., *Echium vulgare* L.);
- conformational variability of the internal tissues of the leaf (*Berteroa incana* (L.) DC., *Euphorbia seguieriana* Neck., *Reseda lutea* L., *Eupatorium cannabinum* L., *Chenopodium album* L., *Kochia laniflora* (S. G. Gmel.) Borb.);
- teratological manifestations in the flower (*Capsella bursa-pastoris* (L.) Medik., *Echium vulgare* L., *Convolvulus arvensis* L., *Oberna behen* (L.) Ikonn., *Reseda lutea* L.);
- variability in the male generative sphere – defective pollen (*Dactylis glomerata* L., *Berteroa incana* (L.) DC., *Digitalis purpurea* L., *Polygonum aviculare* L., *Reseda lutea* L.);
- variability in the female generative sphere – defective ovules (*Polygonum aviculare* L., *Echium vulgare* L., *Capsella bursa-pastoris* (L.) Medik., *Salsola australis* R. Br., *Dactylis glomerata* L., *Reseda lutea* L.);
- genetic heterogeneity of seeds (*Ambrosia artemisiifolia* L., *Capsella bursa-pastoris* (L.) Medik., *Reseda lutea* L., *Echium vulgare* L., *Polygonum aviculare* L.);
- morphological heterogeneity of fruit (*Berteroa incana* (L.) DC., *Capsella bursa-pastoris* (L.) Medik., *Echium vulgare* L., *Amaranthus retroflexus* L., *Artemisia absinthium* L., *Anthoxanthum odoratum* L., *Cynoglossum officinale* L., *Diplotaxis tenuifolia* (L.) DC., *Artemisia vulgaris* L., *Reseda lutea* L.);
- histochemical heterogeneity of fruit (*Berteroa incana* (L.) DC., *Echium vulgare* L., *Capsella bursa-pastoris* (L.) Medik., *Cirsium arvense* (L.) Scop., *Daucus carota* L., *Artemisia absinthium* L., *Stenactis annua* Nees, *Anthoxanthum odoratum* L., *Xanthium albinum* (Widd.) H. Scholz, *Artemisia vulgaris* L., *Reseda lutea* L.);
- detection of deviations during seed germination (*Capsella bursa-pastoris* (L.) Medik., *Lactuca tatarica* (L.) C. A. Mey., *Amaranthus retroflexus* L., *Polygonum aviculare* L., *Echium vulgare* L., *Agrostis stolonifera* L., *Oberna behen* (L.) Ikonn., *Salsola australis* R. Br., *Reseda lutea* L.);
- general generative transformation subpopulations (*Berteroa incana* (L.) DC., *Kochia laniflora* (S. G. Gmel.) Borb., *Capsella bursa-pastoris* (L.) Medik., *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Echium vulgare* L., *Deschampsia caespitosa* (L.) Beauv., *Galium mollugo* L., *Reseda lutea* L.);
- disorientation in life strategy (*Berteroa incana* (L.) DC., *Calamagrostis epigeios* (L.) Roth, *Capsella bursa-pastoris* (L.) Medik., *Arrhenaterum elatius* (L.) J. et C. Presl., *Swida alba* Opiz, *Cyclachaena xanthiifolia* (Nutt.) Fresen., *Reseda lutea* L., *Echium vulgare* L.).

Bioassessment programs are often required to make do with available tools to fulfill regulatory mandates, yet they lack resources to evaluate the tools for applications in all habitats of concern. Although all sampling methods in this study suffered from poor efficiency in collecting organisms, the margin – center – margin modification of reach-wide method greatly improved efficacy and reduced the frequency of rejected samples. Furthermore, the lack of significant disagreements and inconsistencies suggests that the MCM method produced results that were comparable to the other methods already in use in California [9], which may facilitate integration of historical data sets. Therefore, we recommend the use of margin–center–margin modification of reach-wide method in low-gradient streams in California as a substitute for the currently preferred method. In conclusion, bioassessment programs can improve data quality and avoid unnecessary expenses by explicitly evaluating assessment tools when assessing novel habitat types.

There are, however, drawbacks to relational databases. They are more complex than simple data tables or collections of files; they can require proprietary software that must be maintained, upgraded, and paid for annually; and they require more information technology expertise to set up and maintain. The advantages of constraint checking have been mentioned, but constraints require expertise to define and implement, and they come with a «hassle factor». For example, constraints may need to be temporarily removed to unload and replace records if corrections are needed. Accommodating new data that require changes to the structure of the database can also present challenges. Some redesign of the database may be needed to accommodate the new data and this may have consequences for how existing data is represented and stored in the database.

Finally, ensuring long-term permanence of data in relational databases, after the project and its funding end, requires more planning and documentation than for data in simple file-based systems. It is worth considering different approaches than the relational database model. Simpler approaches may be more appropriate, depending on the scope of the programs and the volume and types of data to be collected. For example, flat files, such as spreadsheets or comma-separated-values files, can hold data and much metadata in an intuitive layout (e.g., NARSTO Quality Systems Science Center) that is easier for subject matter experts to understand and analyze. They may more easily accommodate changed data structures; if the changes are too great, an entirely new layout can easily be devised for the changed data.

Flat files may be easier to place in a permanent data archive. Challenges in designing and working with flat files include the difficulty of performing integrated analyses on data in differently structured files; safely changing or correcting the same element of basic information when it is contained in many records, and the issue of documenting the associated information (site location and type, sampling and analysis methods, etc.). The emergence of metadata standards and tools, previously discussed, helps immensely with this last issue.

Whatever the type of data management system, funding for central data management is vital for long-term multiinvestigator projects. Funding must be commensurate with the volume and complexity of the data. It should commence very early in the project to permit sufficient time to understand the data that will be generated and the needs of the users. It should last beyond the traditional end of the project, to support acquiring the final data into the database, assembling or creating the needed permanent documentation, and providing the data to a permanent data archive.

A permanent archive should be selected well before the end of the project, and perhaps even at the beginning. Possibilities include EPA’s STORET system (EPA 2008) [2], although using this requires that the data be in a particular structure, which is obviously easiest if this was adopted at the project outset. Other possibilities include a NASA Data Active Archive Center, which is particularly suitable for data in flat files.

Finally, the importance of good data management practices in the environmental sciences is becoming increasingly recognized and supported. The National Science Foundation has recently initiated a multi-year, multiinstitution project known as DataONE (Data Observation Network for Earth [2]). This project will develop, provide, and foster a variety of cyberinfrastructure resources to support scientific data management. Educational institutions are also expected to include more data management concepts in science curricula. The Long Term Ecological Research (LTER) community has, over the last decade or two, recognized, confronted, and studied these issues. Effective data management tools should become increasingly available. Long-term biomonitoring programs should therefore find it increasingly easier to meet the challenge of documenting and preserving their valuable data for use by future generations of scientists.

An important element in the valuation of natural ecosystems is the establishment of signal indicators – the so called indication criteria that allow to judge with a certain probability the level of transformation and ecosystem depletion, to determine the real and energy balances in local geosystems.

The theoretical importance of this publication is to identify the information links between the actually existing flows of matter and energy in the development of ecosystems with intensive exploitation of their resources.

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***Сафонов А. І.* Апробація критеріїв екосистемного нормування за фітоіндикаційною складовою. –** Критеріями для встановлення ступеню нормальності екосистеми є показники індикаційної ботанічної експертизи: інформативні трансформації структур рослин-індикаторів, розмах їх екологічної амплітуди та реалізація стратегій видів за новими адаптивними сценаріями.

Ключові слова: індикаційна ботанічна експертиза, трансформації структур рослин-індикаторів.

***Сафонов А. И.* Апробация критериев экосистемного нормирования по фитоиндикационной составляющей. –** Критериями для установления степени нормальности экосистемы являются показатели индикационной ботанической экспертизы: информативные трансформации структур растений-индикаторов, размах их экологической амплитуды и реализация стратегий видов по новым адаптивным сценариям.

Ключевые слова: индикационная ботаническая экспертиза, трансформации структур растений-индикаторов.