USE OF ANIMAL COMMUNITIES' INTEGRAL CHARACTERISTICS FOR THEIR STATE AND SUSTAINABILITY EVALUATION

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Introduction

The evaluation of state and stability of biocoenoses under the conditions of various disturbing factors' (anthropogenic ones among them) action is one of the central problems of ecological systems monitoring. The ideas of "sustainability " and "stability" of the ecological system should be strictly distinguished. These terms have no, for example, strict English analogues and it makes the phenomenon understanding by the scientists of various countries more complicated. The sustainability of ecological systems in our interpretation is their natural property (*the ability to stability*), whereas the system *stability* appears as a characteristic of the system state in time or space and is a full-scale manifestation of the ecosystem properties (sustainability, which is manifested as the system's ability to preserve stability, among them) under certain conditions of the environment [1]. Thereat, the system sustainability should be differentially evaluated at every stage of its ontogenesis (as compared to the "survival" rates) with due account for the system's ontogenesis course, that takes an apparent methodological contradiction off in the term "sustainable development". When solving methodological problems of ecological monitoring, the selection of the criteria, which can be used for the environment state evaluation, is one of the key aspects. There are no unified requirements for the "state vector" of ecosystems and the environment as a whole [2]. One of the most frequently used criteria is the ecological systems' sustainability defined through various functional characteristics. Many quite fairly associate the sustainability of the systems with their biological diversity [3] – Shannon's (H) index of biological diversity [4; 5], meaning by it the characteristic opposite to entropy [6]. It is known that the system sustainability index, for example, in the productial hydrobiology is defined by the formula $U=0.045e^{0.51\ H}$, where e is the base of the natural logarithm, and H - Shannon's index of biological diversity [7].

Yu.N. Litvinov [8] suggests using frame-store graphics of averaged values of species diversity indexes and Shannon's and Simpson's evenness for a vivid sustainability assessment. All these factors, undoubtedly, can be used, but only *under all other conditions being equal* and only as *ones of an ecosystem's other characteristics* reflecting its ability to preserve previous states under the action of some or other factors (resistance sustainability) or to revert to the original state after these factors' effects being removed (elastic sustainability) [1]. For the man impact degree evaluation we suggest using not so much population indexes of separate dominant species or indicator species (most sensitive to some or other factor) as indexes of mammal communities (consumers of various orders) of the explored territories in comparison with the control as reflecting the state of an ecosystem vividly. At this approach not only species-specifity, but also interchangeability of the elements in the system are taken into account [9].

Besides, when carrying out monitoring research of biocenoses, and small mammals (for example, under the action of anthropogenic factors) in particular, it is convenient and necessary to use some *integral* indexes reflecting the qualitative composition, structural and functional features of these communities inclusive of the succession stage, where they are at the moment, for the succession component, according to the right opinion of Puchkovsky S.V. [10], is one of objective causes of ecosystems' sustainability periodical decrease. Such geobiocoenosis state evaluation, according to many specialists, is based on the sum of normalized state indexes of separate diagnostic properties with account of their significance, when aggregated [11]. Due to a well-grounded aggregation of separate indexes we can significantly reduce the number of final parameters, that will allow not only simplifying the mathematical modeling and ecological forecasting processes, but will make the investigation findings more understandable for managerial workers in the area of ecosystem exploitation and nature preservation.

1. Materials and methods

Practical works on the small mammals' communities' state evaluation under the influence of various anthropogenic factors have been carried out by us since 1985 on the Tyumen Region territory. The research covered all natural zones and subzones of the Region. The influence of the following factors on the small mammals' communities has been studied: oil pollution, physical damage of land cover as a result of gas production, fire-induced factors in plume zones of oilfields and during wilderness fires, industrial wood harvesting, HVPL electro-magnetic fields, urbanization, recreation, rural industry, periodical rat extermination, etc. As part of the study a great number of various state factors of small mammals' communities and separate species' populations was considered and their informativeness was evaluated by us. One of the primary objectives of the work was to develop an integrated composite index of the community wellbeing (SSS). The offered indexes' availability is considered as an example of small mammals' communities of oil-contaminated territories of the Central Priobye and derelict lands of the south of the Tyumen Region.

2. Results and Discussing

Proceeding from the functional significance of separate indexes, we suggested using such private parameters, which reflect main structural and functional features of mammals' communities, in the integral index formula. The factors reflecting the species composition and the ratio of specie in the community, the number of animals of every species and qualitative biological features of separate species in terms of their individual sustainability to a disturbing factor should be considered as the last by all means. The calculation of individual anthropogenic adaptedness index (I_i), which can be defined by the formula: $I_i=100/[A+B+Kr+((C+E)/2)]$ [12], is supposed for every i-species in a community of small mammals, all the species having to be distributed on the gradation of 5 scales: 1) the K-r-species orientation index (Kr) (from r-strategists through r-oriented, r=K-strategists and K-oriented species to K-strategists – 1, 2, 3, 4 and 5 points accordingly); 2) the degree of athropophobia (A) (from eusinathropi through sinathropi, anthropophiles and "neutrals" to anthropophobes – from 1 to 5 points); 3) the degree of consumptiveness (B) (from seed-eaters and frugivores through eaters of vegetative parts of plants, omnivores and invertebrate eaters to carnivores – from 1 to 5 points); 4) preferable humidity (C) and 5) closedness (E) of dwelling places (from dry through humid to moist and from open through semi-open to closed ones – 1, 2 and 3 points in each scale). This classification and calculation of individual indexes are performed by us for the mammals of Western Siberia (the data are put in special tables) [28], but can be calculated by researchers independently for other regions. On the basis of these indexes (I_i) and the abundance of concrete species (n_i) in the community of mammals its original ecological characteristics are calculated: the eusinathropy factor Is - $Is=(\sum(ES_i*I_i))/(\sum(n_i*I_i))$, where ES_i - is the abundance of every i-eusinathropous species; $\sum n_i = N$, where N – the total abundance of beasties; the anthropogenization index Ia - $Ia=(\sum(ES_i*I_i)+\sum(S_i*I_i))/(\sum(n_i*I_i))$, where S_i - is the abundance of every i-sinathropous species; the anthropophilia factor If - $If=(\sum(ES_i*I_i)+\sum(S_i*I_i)+\sum(FI_i*I_i))/(\sum(n_i*I_i))$, where FI_i - is the abundance of every i-athropophilic species; the naturalness index Ie - $Ie=(\sum(NT_i*I_i)+\sum(FO_i*I_i))/(\sum(n_i*I_i))$, where NT_i – the abundance of "neutral" species, FO_i – the abundance of anthropophobes; the vulnerability factor Ir - $Ir=(\sum(FO_i*I_i))/(\sum(n_i*I_i))$. On the ground of these factors the index of anthropogenic adaptedness for the whole community of small mammals is calculated: IAA=(If-Ir)/Ie*100% (but with Ie=0 IAA is taken to be equal to 100%). This is an integral characteristic of the community. The more species from the groups of eusinathropi, sinathropi and anthropophiles with higher individual indexes I_i and the less "neutrals" and anthropophobes is in the community, the higher will be the integral characteristic. V.S. Smirnov in his personal comment for our work offered using $\ln I_i$ instead of I_i to avoid the skewness of index distribution. We think it to be unnecessary as this factor in our interpretation is not a probabilistic observation either originally or in the further use, and the difference in the logarithmic factor is less prominent.

The overall sustainability of the community (the sum of the elastic and resistant components) is based on the community's thermodynamic features of and can be calculated by the formula:

$$U=0.09e^{(D(2G+3T)/G)}+0.9D(1+K/R)$$

[1, 28], where the first summand is the elastic sustainability($U_u=0.09e^{(D(2G+3T)/G)}$), and the second summand – the resistant sustainability ($U_r=0.9D(1+K/R)$); e=2.718 – the base of the natural logarithm, $D=1-\Sigma(n_i/N)$ – Simpson's index of species diversity; the use of this index compared to Shannon's one gives less weight to exotic species, that, proceeding from the postulate of the "system redundancy" [16] due to bridge links, from our point of view, allows not overestimating their role in the system sustainability; $R=(V-1)/\lg N$ – species wealth, V – the number of species, N – total number of species, T – the succession stage of the ecosystem. With $0<T<0.2$ the pioneer community takes place, with $0.2<T<0.3$ – the young one, with $0.3<T<0.5$ – the transitional one, with $0.5<T<0.9$ – mature one, and with T=1 – the climax community; К – the medium "viscosity" coefficient (from 1 to 10), G – the medium "elasticity" coefficient (from 1 to 0.1 accordingly), the last two factors are defined for every natural zone or subzone of Earth [12] or a concrete region (for Western Siberia they are put by us into a special table):

Table 1. The scale of medium "viscosity" (K) and "elasticity" (G) for natural subzones

Natural subzone	К	G
Arctic tundra	2,5	0,85
Typical tundra	3,0	0,80
Southern tundra	3,2	0,78
Forest tundra	3,5	0,75
Northern taiga	4,0	0,70
Middle taiga	4,5	0,65
Southern taiga	5,0	0,60
Subtaiga	5,5	0,55
Northern forest steppe	6,0	0,50
Middle forest steppe	5,8	0,53
Southern forest steppe	5,5	0,55
Steppe	5,0	0,6

It is easy to notice that with a "null" community (i.e. in the absence of species in a given land area) its sustainability is not equal to null, and makes the minimal value equal to

0.09. This is the so called “vacuum sustainability”, which requires much energy and efforts to be negotiated.

The factors reflecting sex and age structures of small mammals’ populations and communities as a whole are also a very important one. The conservatism index (IKV) suggested by us is formed of the parts of most conservative groups in the populations of small mammals: does and overwintered animals - IKV=(FE/N)+(ZZ/N), where FE is the number of does, and ZZ – the number of overwintered animals. The reproductive processes largely defining a further destiny of separate species populations and the community are offered to be evaluated by the reproduction success index (URZ) expressed as the per cent of the young animals number, which could potentially be produced by 100 does in given conditions for one geniture: $URZ=\{[\frac{BS}{FE}100((\frac{EM}{BS}100(100-\frac{RE}{EM}100))/100)] / [\frac{EM}{BS}100]\}*100$, where BS is the number of pregnant does; FE – the total number of does in the community; EM – the total number of embryos; RE – the number of reabsorbing embryos.

And finally, an important factor, in our opinion, is the community areal structure, which we evaluate by the aggregation index. The aggregation index, after Yu. Odum [13], is offered to be calculated by the formula: AG=d/m, where m is the arithmetical mean of the species abundance in the studied area (on separate grounds), d – the dispersion. However, let us remind that the increase of organisms’ aggregation can be caused both by the local animal abundance increase at their constant abundance due to the habitat conditions enhancement in these separate loci and by the total abundance decrease with the preservation of animals only in some more favourable parts of the area at the given (generally unfavorable) conditions. Just taking into account the second case we offered the index of “bad” aggregation for the environmental quality evaluation: BAG=AG/N [14].

After the indexation of the above described parameters the integral index can be suggested. This composite index of the small mammals’ community well-being (SSS) is formed of the indexed parameters of the community and can be defined, for example, by the formula:

$$SSS = U + 0.1\ IKV + 0.01\ IAA + 0.01\ URZ + (0.1/BAG).$$

In the small mammals’ communities considered by us the results testifying the adequacy of the used parameters have been obtained.

Moreover, from the reaction to various anthropogenic actions it is seen that the composite index of the communities’ well-being behaves in a similar way without showing specificity; that, taking into account specific methodological requirements for the criteria of state factors, testifies to ample opportunities of using it during the ecological monitoring.

The composite index of well-being in the communities of small mammals of oil-contaminated lands logically grows from the grounds with severe contamination to the control areas, where exceeds the first almost by an order. However, in the studied small mammals’ communities in the farming lands it authentically grows from young fields to old ones, in the idle field it being 3 times higher, than in derelict lands.

From the factors connected with thermodynamic and informative properties of the studied systems, certainly, the small mammals’ communities’ overall sustainability defined by the species diversity and species wealth and not evaluating the species qualitative composition in the community stands out. This factor largely defines the well-being composite index value (especially in stable communities). The coefficients of the overall sustainability (U) and oil pollution degree and the stage of earlier tilled lands' recovery correlation make accordingly - 0,99±0,07 и 0,94±0,24.

From the oil-contaminated and derelict lands' small mammals' communities' state intermediate factors considering the specificity of the animal species composition the anthropogenic adaptedness index, which on the results of the dispersion analysis is defined by the action of corresponding studied factors by 74,3 and 65,5 %, made a good showing of itself. Moreover, the IAA and SSS correlation coefficients together with the acting factors make accordingly 0,82±0,40 and -0,99±0,06 at oil contamination; -0,88±0,33 and 0,95±0,23 at the derelict lands' recovery.

The index to define the environmental quality on the given parameter (DSSS) can be calculated under monitoring conditions from the formula: $DSSS=(\Delta X/X_ф)*100\%$, where ΔX is the deviation of the given parameter value from the background one (control or original), $X_ф$ – the background parameter value. In our case the deviation of the small mammals' communities' well-being composite index from the control makes, for example, 86,8 % at a severe oil contamination and 41,3 % - at a mild contamination. The small mammals' communities' well-being composite index deviates by 77,7% from the background in farming lands with grain plantings.

Conclusion

Thus, a complex of factors defining the state of mammals' communities and formed of a range of adequate and representative parameters is offered in our work. A small mammals' communities' well-being composite index integrating indexed values of 6 auxiliary factors mentioned above is introduced. We approved the present approach in the small mammals' community of the Tyumen Region various natural zones affected by different anthropogenic factors. The community's well-being composite index proved itself to be completely adequate, sensitive and non-specific. That allows recommending it to be used in the ecological monitoring system.

For a computerized analysis of the offered factors authors' programs in the GW BASIC programming language («Mammalia», «STATAN») and in MS Excel ("Working place of a mammalogist"), wherein there are original and calculated values of constants and a flexible system of inserted variables for the communities of small mammals of Western Siberia. For other regions these indexes are easily calculated from the offered formulas.

References

1. Gashev S.N. Sustainability of ecological systems // Regional problems of applied ecology. Belgorod: BSU, 1988, p. 132.

2. Beim A.M., Pavlov B.K., Brusilovsky P.M. and others. Methods of forecasting ecological systems // Novosibirsk: Nauka (Science), 1985, p. 128.

3. Izrael Yu.A. Ecology and control for the natural environment state // L.: Gidrometeoizdat, 1979, p. 375.

4. Kogan A.B., Naumov N.P., Rezhabek V.G., Chorayan O.G. Biological cybernetics // M.: Higher School, 1972, p. 384.

5. Alimov A.F. Biodiversity as the community structure characteristic // AS bulletin, biological series, 1998, N4, p. 434.

6. Watt C. Ecology and environmental assets management // M.: Mir (World), 1971, p. 464.

7. Alimov A.F. Productional hydrobiology // M., 1989, p. 152.

8. Litvinov Yu.N. Influence of various nature factors on small mammals' communities' diversity indexes // Present-day biology advances, 2004, V. 124, Issue 6, p. 612.

9. Gashev S.N. Ecological characteristics of mammals' communities // Materials of the Conference "Biological diversity of animals of Siberia" // Tomsk: TSU, 1988, p. 128.

10. Puchkovsky S.V. Evolutionary ecology: scientific foundations of stable development // Biological science and education in pedagogical HEIs // Novosibirsk: NSPU, 2005, Issue 4, p. 3.

11. Pykh Yu.A., Malkina-Pykh I.G. On the environmental state evaluation. Approaches to the problem // Ecology, 1996, N5, p. 323.

12. Gashev S.N. Mammals in the ecological monitoring system (in terms of Tyumen Region) // Tyumen: TSU, 2000, p. 220.

13. Odum Yu. Ecology (in II Volumes) // M.: Mir (World), 1986, p. 328 and 376.

14. Gashev S.N. Index of "bad" aggregation in animals' habitat quality estimation // Mammalogical research. Saint-Petersburg: RAS, 2002, p. 131.