THE DEFINITION AND FORMALIZATION OF CONDITIONS OF STABILITY OF DYNAMICS OF HERBACEOUS PLANTS POPULATIONS WITH USE OF COMPUTER EXPERIMENT

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The possibilities of using of computer visual simulation for the measurement of conditions of sustainable dynamics of herbaceous plant populations are discussed. This work presents the necessary and sufficient conditions of the sustainable development of dynamics of herbaceous plant population using computer visual simulation.

Key words: herbaceous plant population, vitality spectrum, synontogenesis, visual computer model, stability

Actual task of research of plant population is to determine the conditions and algorithm of sustainable development and the principles of self-preservation of natural populations of plant. Studies of populations conducted in different regions and at different objects show that the elementary heterogeneity of populations should be considered as one of the main preconditions for population homeostasis in a changing environment. Undoubted example of such heterogeneity is heterogeneity of individuals in arbitrary population by their age (ontogenetic) and vitality (life) features (characteristics). Finally these properties determine the identity of arbitrary population by age and vitality structures and viability in different locations. Currently two directions are clearly defined in population-based studies. First one is based on the analysis of vitality population structure, topology and its vitality groups' correlation. Second one is focused on the variation of ontogenesis in different environmental conditions (Жиляев, 2005).

It is difficult to study of herbaceous plant populations dynamics of only by empirical methods because it's functioning is realized by a complex algorithm. Its regularities not always can be opened in time scale, which are available by direct observation. Population monitoring in field research rarely exceeds 3-5 years, what is much less than the synontogenesis duration. These challenges require new methods for population research, which includes computer population modelling method, followed by numerical experiments on models (Гіссовський, 2008).

In order to investigate conditions of sustainable herbaceous plant population development a computer model was created that reproduces the space and time principles of herbaceous plant populations functioning and allows visualizing the stages of population development on computer screen. In the first case, the series of experiments were made by the ruderal character population model that replicates the processes of vitality spectrum formation, its typical changes and also organization of spatial mosaic. In the second case research is focused on different ways of complicated synontogenesis, which is typical for the short-rhizomatous species model group of *Soldanella hungarica* L.

In general, the system functioning can be written as following:

$$x(t+1) = F(x(t), \alpha(t), \beta(t), \xi(t)), \qquad (1)$$

where $x(t)$ – is condition of the system at the moment t, $\alpha(t)$ and $\beta(t)$ – are internal and external factors that affect the dynamics of the system, $\xi(t)$ – is random factor, and $F(*)$ – is transition operator from one system condition to the next one. In terms of population viability research, internal factors include the vitality levels dynamics with regards to their life condition, synontogenesis; external factors include anthropogenic impact – with grazing, mowing, picking berries, trampling plants. A detailed description of the model is given in the work of Volodymyr Gissovskyi (Гіссовський, 2010). This work proves that sustainable population development is ensured by changes in the vitality spectrum correlation and is realized as a function of its self-organization, which is manifested by changing vitality structure. Self-organization process is accompanied by varying stages of chaotic dynamics of its vitality spectrum, which forms the preconditions for sustainable population development (Гіссовський, 2012 а). V. Gissovskyi (Гіссовський, 2012 б) deducts the necessary conditions for sustainable population development. Let us denote the vitality of individuals through $f_{ij}(t)$ – individual at the moment t, $j \in J$ – the set of individuals that belongs to the vitality group i, $i \in I = \{Ж\text{-}1, Ж\text{-}2, Ж\text{-}3\}$ – vitality groups. Let us define the vitality for each j by following formula:

$$f_i(t, \lambda_j) = \lambda_j * f_i^b(t) + (1 - \lambda_j) * f_i^m(t), \qquad (1)$$

where $[b, m]$ – the range of individual potential, which depends on the vitality group, and λ –is the option of vitality at the moment t, which takes values from the interval $[0,1]$. Suppose that for all j we define the function $G_i(t)$ as follows:

$$G_i(t) = \max_{\lambda j} \{f_i(t, \lambda_j)\}, \ i \in I \qquad (2)$$

Let us write down conditions

$$G_i(t) \neq G_i(t) \neq G_i(t), \qquad j \in J \qquad (3)$$

$$G_i(t) \cong G_i(t) \cong G_i(t), \qquad j \in J \qquad (4).$$

If condition (3) is fulfilled, the dynamic characteristics obtain features which indicate population viability, and if the condition (4) is fulfilled, the population viability probably has the possibility of decline. Obviously, the system dynamics in the case (3) is stable, and in case (4) – is unstable because in this case the demographic curve amplitude increases sharply, which signals the possible loss of the population stability. It should be emphasized that in this interpretation the correlation of individuals with different vitality is very important, as well as the change of their vitality condition.

On the other hand, population research in recent decades has given grounds to conclude that postembryonic ontogenesis is the basic mechanism that helps to realize autoregulatory functions of all parameters of population. First of all, the option of ontogenesis and generation change of individuals with different vitality in a particular population is shown through the correlation of different-age individuals (ontogenetic spectrum). In its content and complex form, ontogenesis (synontogenesis) can be defined as a set of life cycles of all simple and complex individual generations, syncondyviduals and clones that originate from a single specimen, which in this case originated from the zygote (Жиляев, 2005). It is important that long-term researches on model species showed reversibility of many age states, which contribute ontogenesis to be cyclic and population – to be stable (Жиляєв, 1986).

To formalize the approval of sustainable population conditions, let us consider the classical algebraic structure, which consists of a set of elements and let us set transaction interaction on these elements (Фрид, 1979). The result of this operation is the element that belongs to $\hat{G}$ set. Let us write down pair $<\hat{G}, f>$, which consists of $\hat{G}$ set and includes operation f called **group** if the operation f is satisfying the following axioms (Голод, 2005):

1. For three elements $a, b, c \in \hat{G}$, condition $f(f(a, b), c) = f(a, f(b, c))$ is implemented.
2. There is a neutral element and for an arbitrary element $a \in \hat{G}$, condition $f(e, a) = f(a, e) = a$ is implemented.
3. For each element of the $\hat{G}$ set there is inverse element for which the next feature is implemented $f(a, b) = f(b, a) = e$.

In our case, the biological interpretation of the previous axioms for herbaceous plants can be as follows. The first axiom informs that the age change in synontogenesis can occur in different sequences. This enables population to respond differently on changeable environmental factors and form the diversity of dynamic characteristics in its development. The second axiom shows that individual can remain in the same age state for some period of time. The third axiom implements the reverse features of the synontogenesis. In other words, individual enters the process of rejuvenation, and ontogenesis itself has cyclic elements.

On the other hand, it is known that the objects that can be in some way changed to the original state are called symmetric (Голод, 2005). The modern conception of symmetry declares object permanence to any changes that can be performed on it. Immanent ordering, balance, and therefore stability are the symmetry features. Obviously not all occurring axioms are implemented in different synontogenesis. But it could be affirmed that some herbal plant populations, in which group operation axioms (1)-(3) are implemented, are characterized by sustainable development. And this is a sufficient condition for sustainable development of herbaceous plants population.

Thus, this work considers the hypothetical conditions of herbaceous plant population that provides stable development. It is clear that sustainable development in all cases is a function of population viability. However, not all viable populations are stable. Therefore, it can be concluded that a necessary condition for sustainable population development is the vitality state of the spectrum and implementation of (1)-(3) axioms is sufficient condition. So, on such condition, the algorithm of herbaceous plant populations' research becomes the following. Originally properties of synontogenesis should be investigated using abstract algebra, geometry and discrete mathematics (graph theory, optimization flows). Based on received information, we should apply modern (multi-agent) methods of visual simulation, and study the dynamics and features of the vitality spectrum and population viability based on the obtained numerical and visual results. This will enable to prove numerically the fact of the viability of herbaceous plans population.

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ВИЗНАЧЕННЯ ТА ФОРМАЛІЗАЦІЯ УМОВ СТІЙКОСТІ ДИНАМІКИ РОЗВИТКУ ТРАВ’ЯНИХ РОСЛИН З ВИКОРИСТАННЯМ МОЖЛИВОСТЕЙ КОМП’ЮТЕРНОГО ЕКСПЕРИМЕНТУ

В. Б. ГІССОВСЬКИЙ

У роботі обговорюються результати експериментів, які отримані в результаті функціонування візуальної імітаційної моделі популяції трав’яних рослин з урахуванням їхньої життєздатності. Виведені необхідні та достатні умови стійкового розвитку популяції з використанням структур абстрактної алгебри.

Ключові слова: популяції трав’яних рослин, віталітетний спектр, синонтогенез, візуальна комп’ютерна модель, стійкість

ОПРЕДЕЛЕНИЕ И ФОРМАЛИЗАЦИЯ УСЛОВИЙ УСТОЙЧИВОСТИ ДИНАМИКИ РАЗВИТИЯ ТРАВЯНЫХ РАСТЕНИЙ С ИСПОЛЬЗОВАНИЕМ ВОЗМОЖНОСТЕЙ КОМПЬЮТЕРНОГО ЭКСПЕРИМЕНТА

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В работе представлены результаты экспериментов, которые получены в результате функционирования визуальной компьютерной модели популяции травяных растений с учётом их виталитетного спектра. Выведены необходимые и достаточные условия устойчивого развития популяции с использованием структур абстрактной алгебры.

Ключевые слова: популяции травяных растений, виталитетный спектр, синонтогенез, визуальная компьютерная модель, устойчивость

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