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The problem of conservation of population diversity (w-biodiversity) is less developed than of α-, β- and γ-diversity (taxonomic and biocenotic). It needs long-term population monitoring in specially protected reserves and in man-damaged areas. Population monitoring aims at assessment of state of plant cenopopulations, revealing the effecting mechanisms of outer factors, at regulation of organism and population parameters, at development of methods of cenopopulation conservation and restoration.

Research methods included morphological, morphometrical, population-onthogenetic, demographic, phytocenotic, statistical (first of all, multi-dimensional statistic). Suggested monitoring principles are based on the study of over 500 natural and artificial cenopopulations of 75 vasular-plant species performed in Mary El Republic, in Central and North-West European Russia by staff of the Chair of Botany, Ecology and Plant Physiology, Mary State University. We investigated 9 woody plants (1 tree, 1 shrub, 4 undershrubs and 3 semi-undershrubs); 16 species of annual or few-year herbs and 50 species of herbaceous polycarpics (vertical-root herbs – 11 species, brush-root herbs – 7 species, tuft-forming – 7 species, short-caudex – 10 видов, long-caudex – 6 species; stolon-forming – 7 species; earth-creeping – 2 species). Descriptions of onthogeny of 55 species were published [1, 2, 3, 4, 5, 6]. Program of population monitoring must include several directions of research with different degree of their elaboration, depending on objectives.

On the organism level, biomorph type is described from the point of view of its value for population: monocentric, polycentric, hidden-polycentric and acentric life forms. Further we distinguish morphological and/or phytocenotic calculation units: individual genetes or clone genetes in monocentric and acentric individuals, rametes – partial bushes or shoors (in the absence of particulation) in polycentric and hidden-polycentric individuals, rametes-particules or clonists all above-mentioned biomorphs (figs. 1, 2). Specific features of life forms [7, 8] and shoot types are directly connected to lifetime of cenopopulation elements, to particulation tems, to degree of rametes renewal, and consequently, to the type and duration of onthogeny, to the methods of cenopopulation self-maintenance.
Using the concept of discrete onthogeny description [5, 6, 9, 10, 11, 12] allows to detect age stages in earlier non-studied species belonging to similar life forms on the basis of macro-morphological, morphometrical and physio-biochemical parameters. Figures 1 and 2 depict onthogenetic stages of full onthogeny of Chelidonium majus L. [13], Potentilla anserina L., Pulmonaria obscura Dumort., Lysimachia nummularia L. [5]. Main criteria for distinguishing these onthogenetic stages are way of nutrition (connection to seed), existence of embryonic, juvenile or mature structures, capacity for vegetative reproduction, balance between renewal and dying, grade of main properties of biomorph formed in plants [10, 11, 12]. Code of qualitative properties of each onthogenetic stage of cenopopulation element is specific for plants belonging to close biomorphs. This code is stable enough even under increasing man load. Nowadays this concept is applied to higher spore plants, e.g. ferns [14] and even lichens [15].

Alongside with stable indicative onthogenetic symptoms, cenopopulation elements possess over polyvariant development. According to suggested classification [16, 17], we distinguish between structural polyvariance (including size, morphology and reproduction) and dynamic polyvariance (dynamics and development rate). This concept is applied in monitoring with differential assessment of intrapopulation diversity for description of vitality, bio-morphological and pheno-rhythmological sub-groups and classes on the basis of development rates. Dynamic polyvariance (including morphology, size, reproduction, rhythms and dynamics of development rate) has been described. All species belonging to one or close biomorphs have similar manifestations of onthogeny polyvariance.

Figure 3 analyzes size polyvariance in different onthogeny stages of Chelidonium majus and displays considerable diminishing of plant size owing to competition for water and mineral nutrients. Thus, life status of elements determine biomass and productivity of cenopopulation.

Nowadays the Chair of Botany, Ecology and Physiology of Mary University collected vast material in populations of over 70 species of herbs, shrubs and undershrubs allowing to assess morphological heterogeneity of populations in detail [17, 18, 19]. Monitoring development of morpho-structures allows to distinguish between 2 main modes of morphological changes: 1) changing algorithms of differentiation of root and shoot germs or their elements; 2) increasing number of growth points of roots and shoots. Obtained results allow to state
that morphological change modes are unique in plant vegetative and generative spheres [17, 18, 19]. When selecting the symptoms, one must prefer more flexible symptoms responding to environmental effects and symptoms entailing greater population aftereffects. E.g.
changing intensity of shoot and root branching in *Dactylis glomerata* L. often causes increasing phytomass, phytogenic field area and plant competitive capacity. On the other hand, forming other variants of metamorphic underground stolones in creeping crowfoot (*Rapunculus* ssp.),
nunculus repens L.), root sprouts in lance-leaf plantain (Plantago lanceolata L.) [21], ‘bulbs’ in inflorescence of Deschampsia caespitosa (L.) Beauv.) promote additional reproduction methods. Increasing components of seed productivity (number of generative shoots, inflorescences, flowers) in major plantain (Plantago major L.) [17] and blue lungwort (Polemonium caeruleum L.) [20] enhance possibility of seed self-maintenance of populations. At last, changing shoot cycles, time of particulation and lifetime of rametes in water plantain (Alisma plantago-aquatica L.) and Pl. Lanceolata provide for changing onthogeny duration. Changing plant life form is most vivid manifestation of polyvariance.

Population monitoring of cenopopulation P. major registered 12 variants of life forms (fig. 3). 2 sub-species of great plantain P. major ss major and P. ss pleiosperma differ in growth direction of generative shoots. In first case they are as a rule orthotropic and in the second case slunting-apogeotropic, although preserving general type of brushroot biomorph (fig. 3.2). In some cases mature plants of both sub-species preserve main root, then life form can be described as ‘vertical short caudex with a mixed type of root system', or as

![Figure 3.](image-url)
Early death of apical bud of main shoot causes development of filial rosette shoots and plagiotropic growth of caudex (fig. 3.5). Most abrupt changes of biomass are caused by mildew forming two-rosette plants (fig. 3.6) and by herbicides (changing leaf form, entailing merging stem and leaf, forming multi-rosette plants). Consequently, macro-morphological properties of cenopopulation elements can serve markers man-induced or fungi-induced impacts which is valuable for assessment of cenopopulation state. Further development of plant populational morphology will provide for greater use of macro-morphological symptoms for indicating environmental conditions.

Dynamic polyvariance also maintains heterogeneity in cenopopulation and allows to register asynchronic seasonal development of various phenorhythmogroups (fig. 4 featuring silver birch Betula pendula Roth.) in different levels of pollution in Yoshkar-Ola town [22]. It also registers different rates of onthogenetic development (tab.). In the course of life of individuals or rametes, they change their development rate. It is manifested in different duration of various onthogenetic stages. Transition from accelerated development to normal or retarded one is possible, till temporal rest or reverse development. Diversity of combinations of these processes on each
Case studies

Frequency of classes of temporal polyvariance in vertical-root, brush-root and short-caudex plants, %

<table>
<thead>
<tr>
<th>Indices of temporal polyvariance</th>
<th>Chelidonium majus</th>
<th>Valeriana officinalis</th>
<th>Polemonium caeruleum</th>
<th>Plantago major</th>
<th>P. lanceolata</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal development</td>
<td>3.4-50.2</td>
<td>9.1-100.0</td>
<td>4.7-23.0</td>
<td>5.0-83.0</td>
<td>13.3-93.3</td>
</tr>
<tr>
<td>Accelerated development</td>
<td>19.3-69.6</td>
<td>9.1-100.0</td>
<td>27.3-85.7</td>
<td>79.0-86.0</td>
<td>0-33.3</td>
</tr>
<tr>
<td>Retarded development</td>
<td>24.7-32.7</td>
<td>9.1-90.9</td>
<td>0-42.0</td>
<td>0-24.0</td>
<td>6.7-33.3</td>
</tr>
<tr>
<td>Temporal rest</td>
<td>–</td>
<td>–</td>
<td>9.5-39.5</td>
<td>0-9.0</td>
<td>0-26.7</td>
</tr>
<tr>
<td>Re-youth</td>
<td>–</td>
<td>0-44.4</td>
<td>3.3-6.0</td>
<td>10.0-42.0</td>
<td>0-13.3</td>
</tr>
</tbody>
</table>

Ontogeny stage provides stipulates existence of multiple ways of individual development for the elements. Really, each individual or other element of cenopopulation has its unique development path. In this case the words «each plant is individual» is true [16].

In certain cases, the number of realized ontogenetic ways depends on the impact of biotic and abiotic factors and reaches 0.1-50% [22]. It is minimal in extremely stress and in optimal conditions. It is maximal in moderate adverse conditions. It allows to suggest that «favourable regime» can not provide for maximal realization of plant capacities.

That is why detection of modal ways of ontogeny of elements with high productivity or tolerance, detection possible effect ranges for different factors is an important condition for developing the strategy of grassland management [23].

Developmental polyvariance provides for maximal adaptation to changing environment within potential capacity of each specie. We work out a concept of ontogenetic polyvariance revealing connection between dynamic processes on organism and population levels.

We revealed ontogenetic heterogeneity of cenopopulation by detecting the frequency of different ontogenetic groups and plotting age spectra for each observation year. 2-3-fold monitoring during the season is necessary for studying forms with a short ontogeny. Express-monitoring assesses age structure of cenopopulation using the simplest classification [9] with 3 types: invasion, normal or regressive cenopopulations. More elaborate analysis applies detailed classifications [11, 12], splitting normal cenopopulations into young...
(v-g1), mature (g2), aging (g3) and old (ss) normal cenopopulations [24, 25] grounding on maximal value of one of adult age groups. L.A. Zhivotovsky (2001) [5], used two criteria - age index (D) and effective density index (w) launched gradations of young, intermediate, maturing, mature, aging and old cenopopulations.

Cenopopulation age coefficient can be used for assessing age stage of cenopopulation [10]:

$$\Delta = \Sigma K_i n_i / N,$$

where $K_i$ - cost of i-age stage, $n_i$ - density (number) of i-age group, $N$ - density or number of cenopopulation. Variation range between 0 and 1. The higher $\Delta$ is, the older cenopopulation is.

In long-term monitoring it is often necessary to compare yearly cenopopulation dynamics. Then one must calculate cenopopulation development rate or specific rate of cenopopulation development [6]:

$$V_\Delta = \Delta t - \Delta_1 / T_1 - T_t; r_\Delta = \Delta t - \Delta_1 / \Delta_1(T_1 - T_t).$$

Allowing to distinguish types of cenopopulation dynamics in different phytocenoses under various tension of man-induced or other environmental factors. Analysis of materials of 25-year-long monitoring of yearly dynamics of *Deschampsia caespitosa* on the 60-year-old grazeland and hay-making fields of Dedinovskaya floodplain revealed the dominance of wave-type succession dynamic type with distinct population waves [16].

Analysis of variability in cenopopulation of *Deschampsia caespitosa* in different sites of its area within European Russia and Ukraine Carpathian displayed similar dynamic trends in different climate conditions and under similar man impact, although cenopopulation development may differ in rate, determining different rate of generations rotation, different type of re-structuring age and spatial structure.

For most plants, life of cenopopulation consists of several stages with different rate of dynamic processes. Successive changes demonstrate quick transition from invasions to normal cenopopulations, quick aging of the latter until regression. Abrupt decreasing of density may alternate with increasing. Renewal waves proceed continuously or wither, then cenopopulation is few-numbered with slight fluctuations. It is followed by new propagation outburst, new renewal and acceleration of cenopopulation development. It repeats several times. Therefore, succession dynamic type in population flow can be followed by fluctuation type, again by succession and so on during long-term (or short-term) existence of cenopopulation. On the whole,
there are wave-succession, wave-demutation and wave-fluctuation processes [16].

In order to study spatial structure of cenopopulation one must map location of individuals and rametes on permanent transects or grounds, fix up sizes of phytogenic fields, their adjoining or overlapping in order to define the borders of accumulations and algorithms in the «lace» areas of studied species. Accumulation borders can be detected by frontier plants or by other elements of cenopopulation overlapping not less than with two neighbors. Thus, phytogenic fields adjoin and overlap each other as cenopopulation gets elder.

Our research allowed to formulated the following concepts of regularities of behaviour in plant population elements:

1) Any element on any ontogeny stage belongs to a certain ontogeny group and has certain macro-morphological, morphometrical and physio-biochemical properties;

2) Each element has its own age, considered as a part of life potential of individuals, a share of energy accepted in course of life, a measure of passed path [10] (Uranov, 1975). It is expressed through special «cost» of each ontogenetic stage, depending on specie: se – 0.0025, p – 0.0067, j – 0.018, im – 0.0474, v – 0.1192, g1 – 0.27, g2 – 0.5, g3 – 0.731, ss – 0.8808, s – 0.9819, allowing to assess cenopopulation age in monitoring;

3) Each element has its own vitality level and can change it during its development, therefore transiting from one vitality group to another, influencing biological productivity and vitality of cenopopulation on the whole;

4) High morphological variability range of elements on each ontogeny stage (since changing shoot-formation intensity till formation of new biomorph) depends upon their flexibility and the effect of outer factors;

5) Duration of ontogenetic stage (onthochrone) and the whole ontogeny of each element is determined by specific features of life form, outer and inner factors;

6) Elements of cenopopulation, as a rule, develop unequally and change development rate in the course of ontogeny;

7) Time and ways of propagation of elements are more stable, depending on specific features of biomorph, and only stress factors promote emergence of additional ways of reproduction and re-youth of elements;
8) Minimal area of phytogenic field of element is determined by sizes of its above-ground and underground spheres. Mosaic phytogenic fields of elements makes phytogenic field of cenopopulation, forms its spatial structure, influences other species’ cenopopulations, eco-topes and its own elements;

9) Biomass of element, its chemical composition depends on on-thogeny stage, specific physiological and biochemical processes, inner and outer impacts.

For population monitoring for compilation of environmental characteristics of biotopes within studied cenopopulation according to geobotanical descriptions digital versions of indicative scales are used [27, 28, 29, 30].

Seed productivity, soil seed pool and consortium interaction are less used for long-term monitoring, in spite of the fact that these aspects are vital for cenopopulation. Revealing consortium links to phytopathogenic, saprophytic and mycorhize fungi, to plant-feeders, insects and other consorts is important for registering the level of damage of population structure of cenopopulation, for explaining the mechanisms of its sustainability and reasons of shrinking number of rare plants.

Revealing general regularities of plant population life gives new approaches for developing theoretical problems: determining specific features of demographic, vitality and spatial structure of plant populations, specific behaviour and key features of each species.

Population-onthogenetic method introduces reliable monitoring, diagnostic and control methods for biocenologists, ecologists, botanists, forest and grassland experts. They can observe state of cenopopulations of economically valuable, food, fodder or officinal, including rare, plants in natural and artificial communities.

In its turn it will allow to reach applied targets:

1) assess the state and possibility of human use of cenopopulations of any wild plant; 2) detect if rare specie population in a certain area is in critical state; 3) suggest research programs and authority activities for conservation and recover of endangered populations of Red Data Book species; 4) develop programs of reconstruction of forest and grassland biogeocenoses; back up selection of areas for nature reserves; 5) develop regional monitoring programs for biodiversity conservation of certain ecosystems.

Materials obtained from the above-mentioned program reflect different aspects of plant population life in different environment and different man impact.
Efforts of biologists will be futile if present and future generations would not use their knowledge and experience for solving certain environmental tasks, if Earth inhabitants will ignore a simple law: nobody can break natural laws, each break will turn out a trouble for decades and centuries... «If we want to achieve accordance with nature, we should accept her terms in most cases» [31].

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Reference


ONTGENETIC HERBARIUM AS A METHOD OF STUDY OF INTRAPOPULATION BIODIVERSITY

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The end of the 20th century and the beginning of the 21st century are devoted to study of biodiversity [1]. Nowadays, deeper knowledge on population life of plants is necessary for theoretical bases of ecological monitoring, assessment of state of renewable biological recourses. It can be done without population-ontogenetic aspect of studying heterogeneity of populations of officinal plants. Exactly this approach has been developing in Russia since the middle of the XX century. Founders of the original direction – population biology – professors T.A. Rabotnov [2, 3] and A.A. Uranov [4, 5] – formulated the concept of discrete description of individual development and ontogenetic heterogeneity of populations of plants. Their followers developed algorithms of distinguishing ontogenetic states of plants of different biomorths [6-15].

Development of population-ontogenetic approach in Moscow, Yoshkar-Ola, Novosibirsk, Voronezh, Kostroma, Lvov, Tver, Syktyvkar, Samara, Kazan etc. showed that deep study of population life of plants and the analysis of heterogeneity of their populations is not possible without detail description of full ontogenesis of individuals.

Ontogenesis – individual development of organism. This is the most widespread biological interpretation, specified and enlarged by different authors [16]. For modular organisms, such as plants, fungi and some animals (sponges, hydroids, corals, pearlwarts) the following definition can be accepted: full ontogenesis is genetically conditioned full succession of all stages of development of one individual or a number of generations from zygote or any other diaspora till natural death at final stages as a result of senescence [17].

It coincides with the idea of a long life cycle or full development of genet [18]. In the case of earlier death or its appearance from vegetative diaspora, ontogenesis will be incomplete.