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Observations of *Platanthera Bifolia* (l.) Rich. (Orchidaceae) Subpopulation Spatial Structure Dynamics.

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ABSTRACT

The spatial structure of *Platanthera bifolia* (L.) Rich. subpopulations is studied under different environmental conditions. The cartographic material is analyzed on the basis of studying the K-function Ripley (Ripley, 1976, 1977) behavior study, as well as using the pair correlation function (Wiegand, Moloney, 2004) and the method of «moving window» on the basis of kernel function (Silverman, 1986; Scott, 1992). It is found out that subpopulations of *P.bifolia* representing all ages have the aggregate discrete-continuum type of spatial structure, and the random distribution of individuals is the indicator of the subpopulation degradation. The seed reproduction of *P.bifolia* is at the base of an important mechanism for the species subpopulation stability - "the movement" of a subpopulation from unfavorable microsites to more optimal ones.

Keywords: *Platanthera bifolia* (L.) Rich., Subpopulation, microsite, population dynamics, spatial and ontogenetic structure.

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INTRODUCTION

The successful protection of rare plant species requires the knowledge of its ecology and the resistance mechanisms of their populations. Traditionally, the population-based studies of plants address the issues of population dynamics and population density, the age structure, the complex variety of ontogenesis and morphological parameters, the seed and vegetative reproduction, the reproduction dependence on the life forms of plants and environmental factors, and others. The issues of spatial population structure regularities are less studied. The analysis of the plant distribution in space is so complex that the testing of various methods for the study of their populations spatial structure is justified (Greig-Smith, 1961; Vasilevich, 1969; Lubarsky, 1976; Zaugolnova, 1982; Galiano, 1982; Wells & Cox, 1991; Haase, 1995 ; Blinova, 1995; Gilman, Dodd, 1998; Wiegand et al., 2004, 2007, Zhukova et al., 2006; Fardeeva et al., 2007; Czarnecka, 2008; Fardeeva et al., 2009; Dodd, 2011, etc.). Most of the spatial analysis mathematical methods ascertain the type of plants spatial distribution as an occasional, regular, aggregate (contagious), but do not evaluate the significance of the spatial structure in the life of populations and their environmental sustainability.

METHODS AND MATERIALS

The object of the study was *Platanthera bifolia* (L.) Rich. - a tuberous orchid, a cryptophyte. The tuberoid is the metamorphosed sprout of reproduction intended for adverse period experiencing (Dressler, 1981). Tuberous orchids are reproduced mainly by seeds. According to its life strategy P. bifolia is a stress-tolerant species, and at the weakening of competition manifests itself as a stress-tolerant-reactive species.

In the 1992-2012 we carried out the observations of the spatial ontogenetic structure of 8 subpopulations (SP) of *P. bifolia* within the territory of the Republic of Tatarstan (European part of Russia). In the botanical and geographical terms the territory belongs to the zone of dark coniferous-deciduous forests. This paper, presents the data (as an example) about 4 subpopulations of P. bifolia. SP-1, SP-2 and SP-3 are confined to the mid-quaternary terrace of the Volga river. SP-1 and SP-2 are grown on the territory of the Volga-Kama Nature Reserve, in the green moss pine forests with birches; first - on the side of a sandy hill, the second - on the relatively flat areas. SP-3 is grown in the suburban forest park "Lebyazhye", in the pine forest with different grass species, in the recreational press conditions. SP-4 is grown on loamy slopes of a watershed plateau in green moss pine forests with spruce (Yash-Ketch v.).

Under the spatial-ontogenetic structure of the population we understand the hierarchical system of distribution areas (images, mosaics) for age groups, the specificity of which is determined by generative plants which reached the morphological realization of the species life-forms, intraspecific and interspecific relations and abiotic environmental conditions. The dynamics of spatio-temporal structure of the subpopulations is seen as a considered as the series of changes in the spatial and ontogenetic patterns of different micro loci in a certain scale of space and time. Micro loci represent the systems of space-time clusters of plants referred to different microenvironments - to different microsites.

The studying of the spatio-ontogenetic subpopulation structure of *P. bifolia* was carried out on the basis of all ontogenetic groups mapping within the test area boundaries of 100-200 m^2. The south-west corner is chosen as the coordinate origin for the areas. The cartographic and descriptive material was structured by the creation of the population electronic database (Chizhikova et al., 2008). To characterize the point patterns of individual plants and its groups of plants that have identified locations the method of K-function Ripley (Ripley, 1976, 1977) construction was used. The deviation of K(r) values, calculated on the test spot mosaic of $K_{CSR}(r)$ values, expected at the spatial randomness allows to judge about the spatial clustering or the regularity of the observed location of individuals for a given radius. To verify the size of the clusters the correlation function (PCF) was also used, computed on the basis of the K-function Ripley (Wiegand, Moloney, 2004). K-function Ripley and PCF were calculated in R environment using the SPATSTAT package (Baddeley, Turner, 2005). The development of density maps using the method of "moving window" (Bailey, Gatrell, 1995) on the basis of kernel functions (Silverman, 1986; Scott, 1992), which reveals the dimensions, the continuity or the fragmentation of the area occupied by population of space was used for the visual analysis of the individuals spatial distribution irregularities.

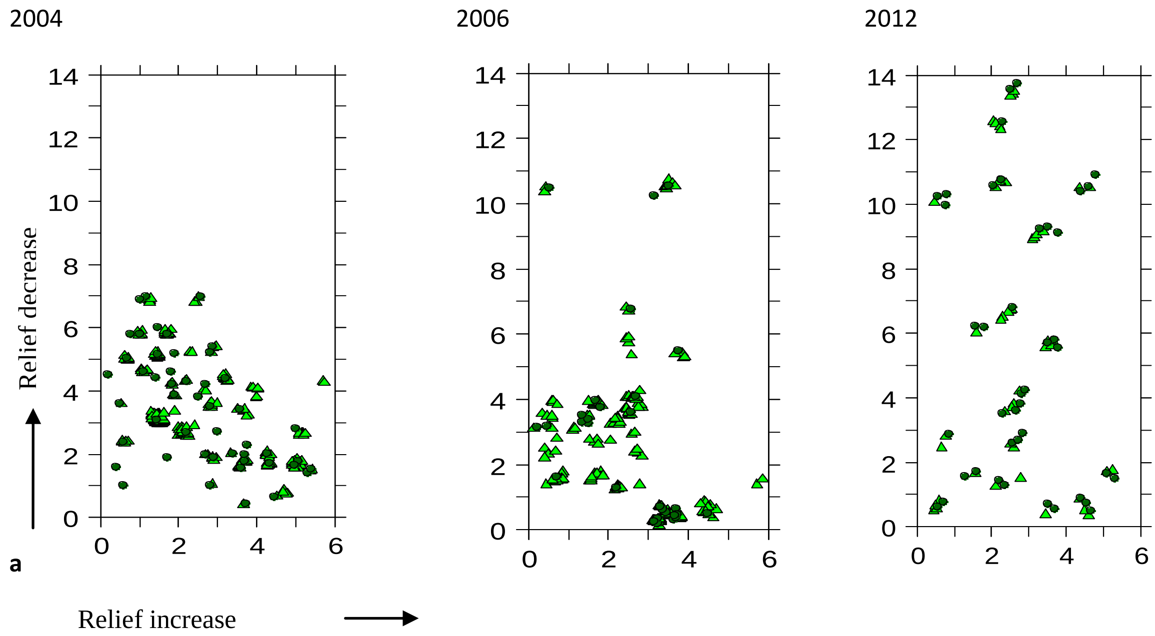
To assess the number of subpopulations variability the variation coefficient was used: $cv = \sigma / M * 100\%$.

RESULTS AND DISCUSSION

The visually observed pattern (spatial pattern) is quite subjective and very different from the objective natural ecological space occupied by the population. So the bank of dormant seeds, protocorms, tubers, individuals which is temporarily at rest is not seen by a researcher. At multiple population mapping, repeated during several years one may determine the conventional boundaries of the ecological area occupied by the population.

During the observation period the significant movement of SP-1 and SP-4 in the space is observed, the spatial structure dynamics for SP-2 was pulsating, and SP-3 was susceptible to degradation, and it disappeared in 2010.

In 1994 SP-1 occupied the upper part of the sand hill; its population made 48 individuals, the average density made 1.25 ind./m². By 2004, SP-1 moved 6 meters down the hill edge. Since 2004, its invasion on the edge of the swampy depression at the base of the mound was observed; the subpopulation amount made 395 individuals, the average density made 9.5 ind./m². In abnormally arid 2010 the number of SP-1 was reduced to 11 individuals, with an average density of 0.2 ind./m². By 2012, the SP-1 environmental space increased, because most part of the swamp dried up and the subpopulation moved to a green moss, sphagnum synusia; the number was increased to 91 individuals. The spatial contours of SP-1 shifted to a reduced portion of the microrelief due to the concentration of its vegetating members in a more favorable microsite (see Fig. 1, a, b). The spatially ontogenetic structure of P. bifolia had an aggregate discrete-continuum type. At the same time with the high population number and SP-1 density in 2004-2006, the second-order polycentric aggregations with 1-1.5 m radius within which small aggregations of the first order are randomly placed with the radius of 0.25-0.5 m. In 2012 the regenerative subpopulation had a low population density and, therefore, the large aggregations of the second order were absent (see Fig. 1, c).



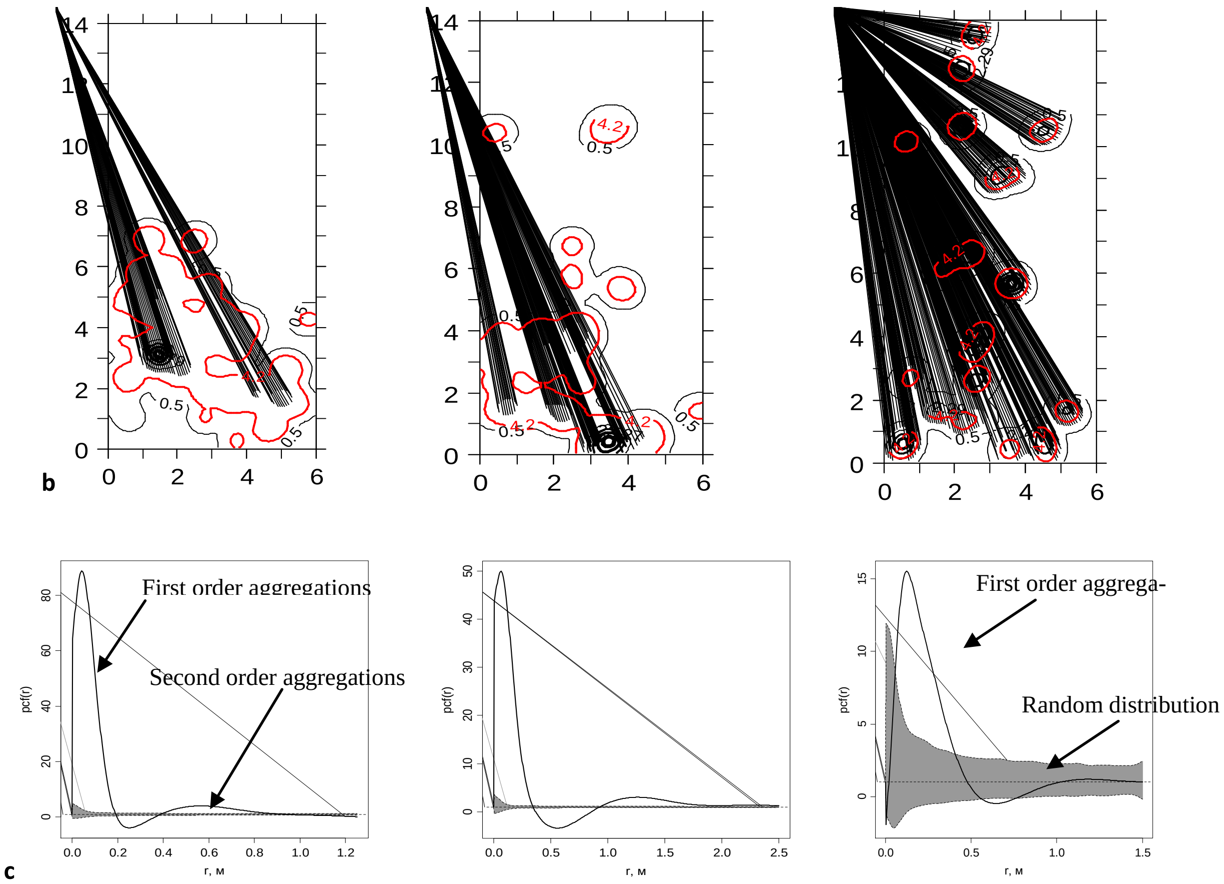


Figure 1: The spatial structure dynamics of SP-1 P. bifolia in 2004-2012:

a - sketch map of the spatial structure (triangles – prereproductive individuals, circles - reproductive individuals); b - density sketch maps developed by «moving window» method; c - the PCF function behavior, reflecting the spatial ontogenetic structure with the formation of I and II order aggregates (by ordinate axis - PCF behavior, by abscissa axis - micro loci radius in meters).

The evaluation of SP-1 spatial structure using PCF fuction during the anomalous 2010 failed because of the low number of plants, but visually their distribution could be described as a random one.

At the sites prone to recreational load noted in the park forest area of city SP-3 was in a depressing state in 2002-2007, the spatial distribution of generative individuals on the area was a random one due to the low number and density.

The moving of SP-1 in the lower part of the relief is related to the drying of the territory, made of sand. Wetted substrate as the limiting factor explains the pulsating nature of SP-2 spatial structure dynamics. Occupying a reduced, sufficiently wetted area, SP-2 during its wet years "goes" beyond to higher relief levels, and during dry years (e.g., after 2010) the subpopulation is "compressed" again - the plants are kept within the optimal microsite boundaries (see Fig. 2).

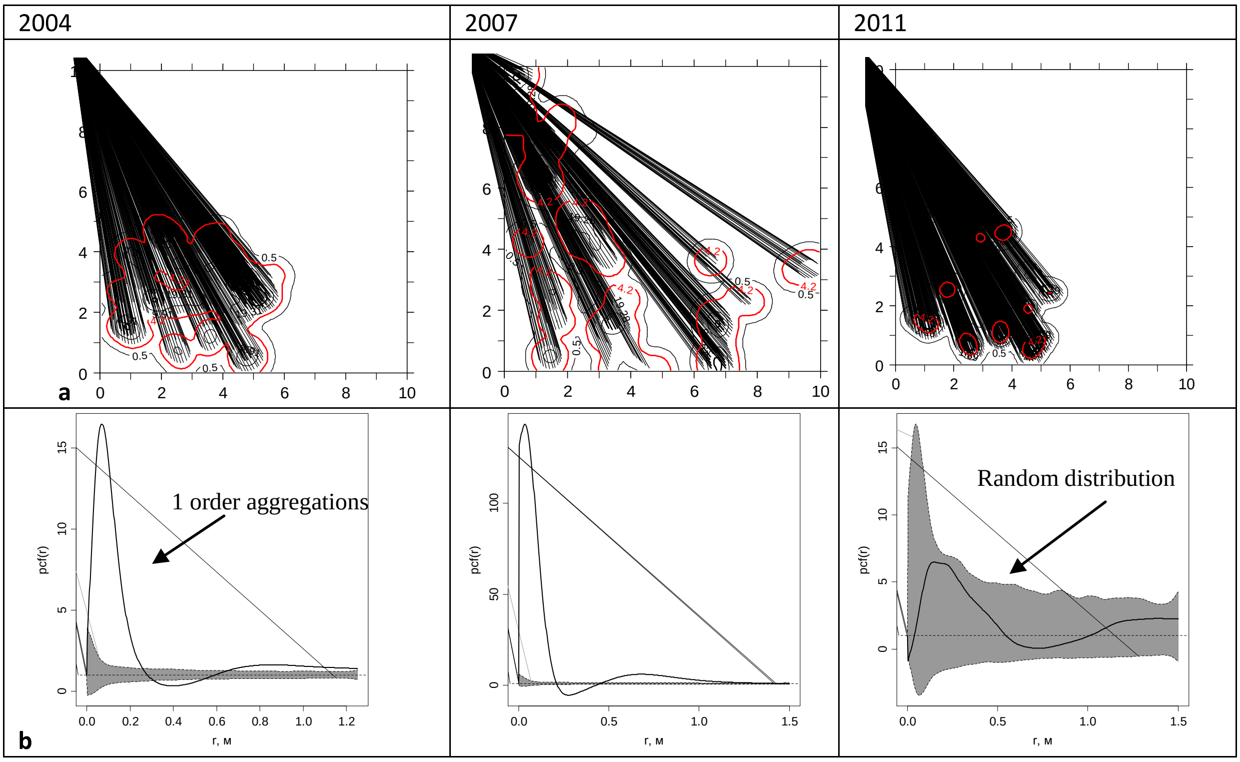
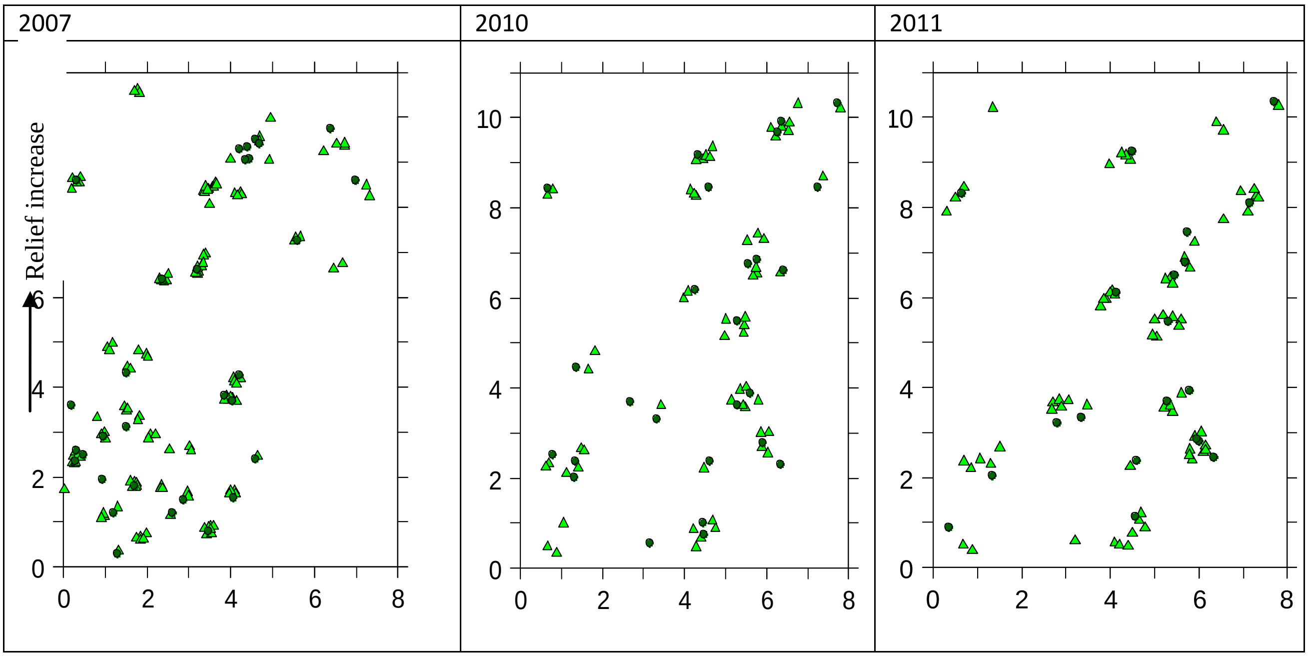


Figure 2. SP-2 P. bifolia spatial structure dynamics in 2004-2011.: a - density charts built by «moving window» method; b - PCF function behavior.

After the drought of 2010, SP-2, with a low number and density had a random spatial structure, i.e. was similar to the spatial structure of generative SP-3 species, subject to anthropogenic pressure (see Fig. 2 b).

In 1990-2001 SP-4 occupied a gentle slope of a forested ravine at the north-western exposure. In 1990-1994 the dynamics of its population was defined as fluctuating one due to the climatic factors. In 1994 its population made 268 individuals. In the second half of the 90s the SP-4 extinction was observed, its dynamics became a unidirectional one; in 2001 the number of this subpopulation made 36 individuals.



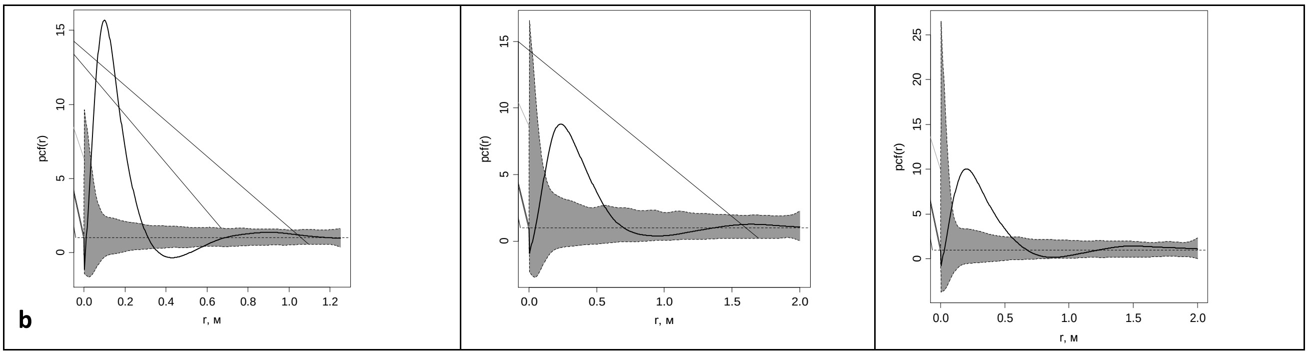


Figure 3. The dynamics of the spatial structure of SP-4 P. bifolia in 2007-2011.

a - the sketch map of spatial structure (triangles - prereproductive individuals, circles - reproductive individuals); b - PCF behavior, demonstrating the spatial ontogenetic structure with the formation of the first order aggregates (by ordinate axis - PCF behavior, by abscissa axis - micro loci radius in m).

In 2007, the plants were found at the foot of the opposite ravine slope - at the slope of south-eastern exposure. The number of plants made 159 individuals, its density made 1.8 ind./M^2. The plants disappeared from the previous place. The reason of SP-4 migration was the replacement succession of forest vegetation on the site. The moderate anthropogenic load on the territory, which oppresses the forest vegetation, allowed P. bifolia to compete with forest and forest-meadow plant species. When this limiting factor disappeared *P. bifolia* became to be superseded by other species. However, on the opposite slope of the south-eastern exposure, with the cessation of anthropogenic load, the soil erosion processes became much slower. This area previously unsuitable for *P. bifolia* growth became an optimal microsite for SP-4.

The spatial ontogenetic structure of SP-4 at the new location has an aggregate discrete-continuum type (see Fig. 3). The distribution of generative individuals of this subpopulation was accidental one only during the abnormally dry summer of 2010. In general, loamy ecotope SP-4 is characterized by a stable moistening mode, compared with sand ecotopes, which is proved by the variability of subpopulations number: during the observation period the coefficient of variation for SP-4 was 55.6% (it made 34.7% for a group of generative individuals), whereas SP-1 makes 98.8% (75.0% for a group of generative individuals).

CONCLUSION

The full age member subpopulations of *P. bifolia* have an aggregate discrete-continuum type of spatial structure, when the discrete loci of the first and second order are distributed on the territory randomly. The discrete loci tend to be full member ones, they have all ontogenetic species groups. The basis of the subpopulation spatial pattern is defined by mature generative individuals who have reached the morphogenesis realization of the species life form. A casual type of the generative individuals group spatial structure or the entire group of individuals may serve as an indicator of the P. bifolia subpopulation degradation.

During the long-term studies of the dynamics of *P. bifolia* subpopulation dynamics the fluctuation changes were often observed concerning the number, density, spatial pattern, which were often caused by the climatic factors. The mechanisms of population stability in terms of the of the gradient factor (humidity, light, etc.) existence one should include the ability of the population to occupy favorable microsites for its existence, the conditions of which are determined by the climatic factor, abiotic environment and interspecific relationship dynamics. The active seed reproduction of *P. bifolia* is at the basis of an important mechanism for the species subpopulation stability - "the movement" of subpopulation from the adverse microsites in more optimal ones.

The reported regularities of spatial and ontogenetic *P. bifolia* subpopulations patterns is characterized, apparently, for all tuberoid orchids. We revealed them for *Orchis militaris* L., *Neottianthe cucullata* (L.) Schlechter, *Dactylorhiza incarnata* (L.) Soo, *D. fuchsii* (Druce) Soo, *D. maculata* (L.) Soo, *Gymnadenia conopsea* (L.) R. Br.

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