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Monitoring of Orchid Populations in a Unique Area of Their Concentration in the Middle Urals

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Abstract—The abundance, density, structure, and dynamics of the populations of 11 rare orchid species are characterized on the basis of observations carried out in the eastern foothills of the Middle Urals from 1991 to 2002. The pattern of changes in the age structure of populations belonging to different ecobiomorphs is revealed. The concept of vegetatively oriented and generatively oriented age spectra of populations is proposed.

Key words: rare plants, orchids, populations, age structure, monitoring, phytodiversity conservation.

Orchids (species of the family Orchidaceae Juss.) continue to receive close attention from ecologists and botanists, which is confirmed by publication in recent years of both reviews (Tatarenko, 1996) and numerous original works dealing with the life cycle and morphogenesis of orchids (Vinogradova and Filin, 1993; Blinova, 1995, 1996, 1998; Vinogradova, 1996, 1999), their reproductive biology (Vereshchagina and Shibanova, 1995), population state and structure (Kagalo *et al.*, 1991; Shibanova, 1994; Puchnina, 1995; D'yachkova *et al.*, 1997; Kulikov, 1997; D'yachkova, 1998; Polyakova *et al.*, 1999), and new habitats (Zagul'skii, 1993; Vakhrameev *et al.*, 1995; Sokolova *et al.*, 1995; Fitsailo, 1998).

Many representatives of the family Orchidaceae are classified as rare and endangered, they have decreased in numbers and have died off in some habitats. For example, 80% of the orchid flora is endangered in northern Belgium (Vanheche, 1993). In Carinthia (Austria), some orchid taxa are in the critical state, because their biotopes have been destroyed (Perko, 1995). Destruction of biotopes and other types of anthropogenic effects on the environment have endangered many populations of orchids in Russia (Vakhrameeva and Denisova, 1983). Some specialists (Vanheche, 1993; Anderson, 1995; Perko, 1995) emphasize the necessity of protecting biotopes in the areas where orchids grow, reducing the load on the environment, preserving traditional techniques of land use, controlling the invasion of synanthropic plant species, recultivating orchids *in vitro*, and introducing them in new areas. Orchids can be regarded as indicators of the degree of ecosystem disturbance (Vakhrameeva, 1992).

Therefore, identification of typical habitats of orchids, analysis of their population structure and dynamics, and development of measures to protect their diversity are of interest.

STUDY REGION, OBJECTS, AND METHODS

Observations over the state and dynamics of orchid populations were carried out in a unique place of their concentration, in the eastern foothills of the Middle Urals near Mount Granatovaya (368 m a.s.l.), 7 km southeast of the village of Verkhnyaya Sysert', Sverdlovsk oblast. According to the landscape zoning (*Atlas Sverdlovskoi oblasti*, 1997), Mount Granatovaya is on a sloping, slightly dissected raised foothill plain composed of igneous–sedimentary and metamorphic rocks. Granites, sometimes with outcrops of quartzites, prevail in this region, where the populations of 11 orchid species are concentrated in a relatively small area (about 280 ha). This is approximately one-third of the total number of orchid species occurring in the Middle Urals (Sverdlovsk and Perm oblasts).

Thus, we studied the populations of 11 orchid species, including one longirhizomatous species *Cypripedium guttatum* Sw.; four brevirhizomatous species *C. calceolus* L., *C. macranthon* Sw., *C. ventricosum*, and *Listera ovata* (L.) R. Br.; one creeping-rhizomatous species *Goodiera repens* (L.) R., Br.; two achlorophyllous rhizomatous species *Neottia nidus-avis* (L.) Rich. and *Corallorhiza trifida* Chatel.; one brevirhizomatous–bulbotuberiferous species *Calypso bulbosa* (L.) Oakes, and two tuberous species *Neottianthe cucullata* (L.) Schlecter and *Platanthera bifolia* (L.) Rich. We characterized these species based on the classification of ecobiomorphs proposed by Tatarenko (1996).

Orchid populations were studied in stationary test plots (10×10 m) established in typical habitats. An elementary unit for assessing the age structure of populations was an individual, i.e., a shoot (particula) in rhizomatous plants forming shoots on the rhizomes and a morphologically and physiologically integral formation in tuberous plants (Rabotnov, 1975; Uranov, 1975).

The age groups of individuals distinguished in the orchid populations were as follows: juvenile (j), immature (im), mature vegetative (vm), young generative (g_1), middle-aged generative (g_2), old generative (g_3), and senile (s). The group of mature vegetative plants comprised both virginal and generative individuals that failed to form generative shoots and, hence, were in the vegetative state in the year of observation. Depending on the ratio between these age groups, we distinguished three types of the age spectra of populations: (1) vegetatively-oriented (with the prevalence of juvenile, immature, or vegetatively mature individuals), (2) generatively-oriented (with the prevalence of generative individuals), and (3) bimodal (with two peaks, one accounted for by vegetative and the other, by generative individuals). Using the terminology of Rabotnov (1950), we classified the populations as invasive, normal, or regressive.

GROWING CONDITIONS FOR ORCHIDS

The populations of orchids studied in this work belong to the communities of birch–pine and pine forests represented by three associations.

Moss-herbaceous pine forest occupies a gentle slope (approximately 5°) of eastern exposure, with soddy podzolic light loamy soil. The tree stand consists of Scotch pine (*Pinus sylvestris*) with a small admixture of weeping birch (*Betula pendula*). Crown density is 60–70%. The shrub layer sometimes includes *Chamaecytisus ruthenicus*. The herbaceous layer with 60–80% coverage consists of *Potentilla erecta, Rubus saxatilis* (cop.$_2$), *Fragaria vesca, Pulmonaria mollis, Trientalis europaea, Viola canina, Aegopodium podagraria, Trollius europaeus, Stachys officinalis, Sanguisorba officinalis* (sp.), *Veronica chamaedrys, Antennaria dioica, Viola hirta* (sol.), etc. The moss layer with the prevalence of *Pleurozium schreberi, Hylocomium splendens*, and *Rhytidiadelphus triquetrus* covers 5–25% of the soil surface.

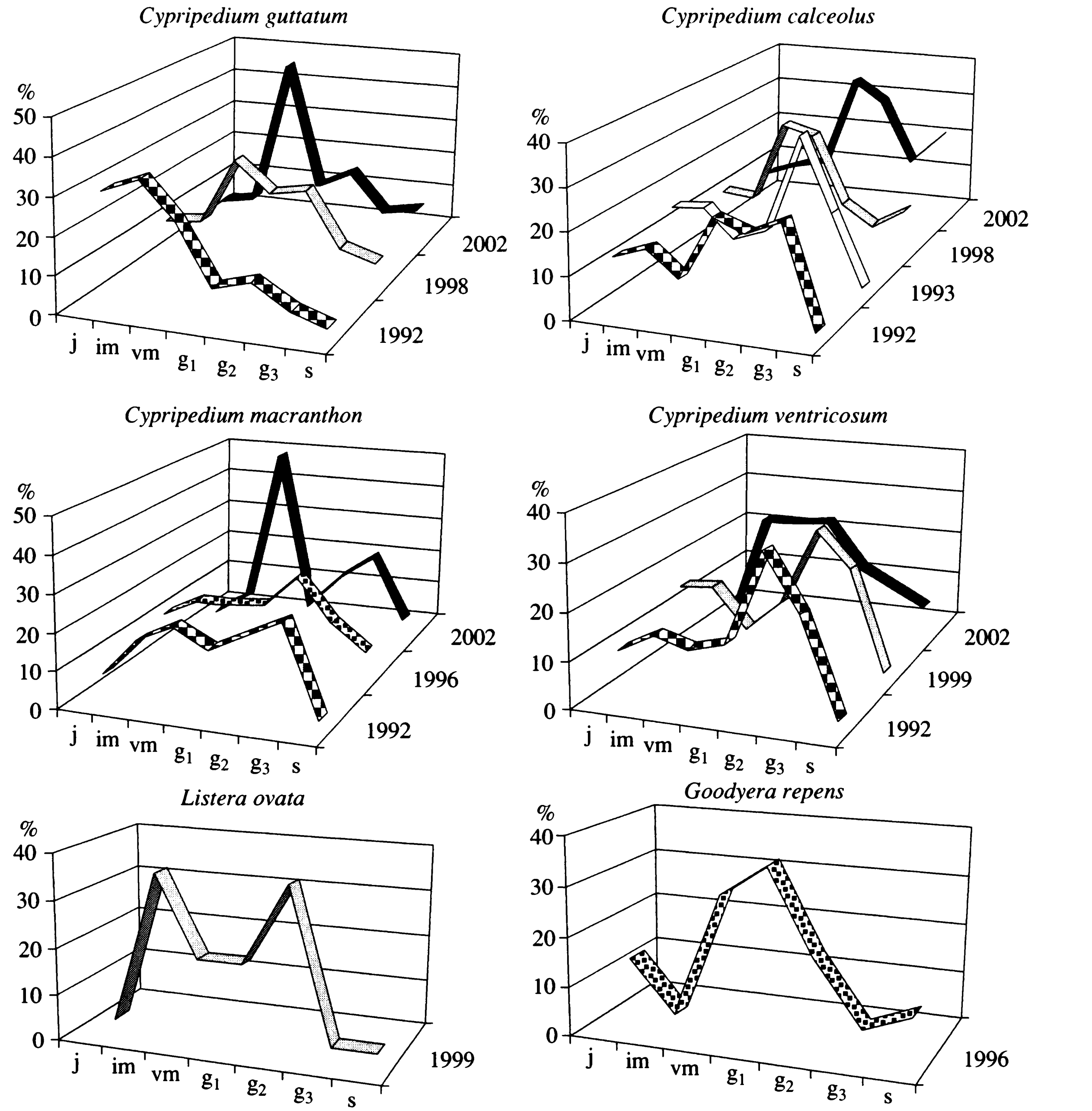
Herbaceous birch–pine forest is situated on a gentle southeastern slope with soddy podzolic light loamy soil. In the undergrowth, *Sorbus aucuparia* is sometimes found. The herbaceous–dwarf shrub layer is well developed, with 80–90% coverage. The species prevailing in this layer are as follows: *Aegopodium podagraria, Chamaenerion angustifolium* (cop.$_2$), *Rubus saxatilis* (sp.–cop.$_1$), *Calamagrostis arundinaceae, Amoria repens, Dactylis glomerata, Galium boreale* (sp.), *Pulmonaria mollis, Pteridium aquilinum, Poa pratensis, Geum rivale, Adenophora lilifolia, Solidago virgaurea, Cirsium heterophyllum, Glechoma hederaceae, Prunella vulgaris, Linnaea borealis, Pimpinella saxifraga, Vaccinium myrtillus, V. vitis-idaea* (sol.), etc.

Herb–grass small-tussock pine forest occupies the lower part of an eastern slope (5–7°). The soil is podzolized loam. The shrub layer is well expressed and dominated by *Chamaecytisus ruthenicus, Rosa glabrifolia*, and *R. acicularis*. The herb–dwarf shrub layer is well developed (80% coverage) and consists of *Calamagrostis arundinaceae, C neglecta* (cop.$_2$), *Melica nutans, Luzula pilosa, Lathyrus vernus, Athyrium filix-femina, Brachypodium pinnatum, Poa pratensis* (sp.–cop.$_1$), *Carex vaginata, Galium boreale, Pyrola chlorantha, Silene nutans* (sp.), *Pteridium aquilinum, Lathyrus pisiformis, Ranunculus polyanthemus, Potentilla erecta, Vaccinium vitis-idaea, Rubus saxatilis, Fragaria vesca* (sol.), etc. *Deschampsia caespitosa* is widespread in moistened depressions, where it forms tussocks 20–40 cm in height and 30–60 cm in diameter. Mosses (*Pleurozium schreberi* and *Rhytidiadelphus triquetrus*) cover approximately 5% of the soil surface.

POPULATION STRUCTURE AND DYNAMICS

Cypripedium guttatum is a longirhizomatous herbaceous perennial. The local population consisted of about 500 partial shoots (individuals), with variations in some years; its density was 80–160 individuals per 0.25 ha. The population is normal and complete (figure). In 1992, its spectrum was vegetatively-oriented: the proportion of vegetative plants in the population reached 82%, including many juvenile (28%) and immature (32%) individuals. The structure of this population markedly changed by 1998: its spectrum became bimodal, with one peak accounted for by vegetative individuals (47%, including 28% of mature vegetative plants), and the other, by generative individuals (49%). A new, although less expressed outburst of vegetative reproduction occurred in 2002. The age spectrum of the population became vegetatively-oriented again: 57% of vegetative individuals, with the obvious prevalence of mature vegetative plants (47%). Senile individuals, which were absent in 1992, comprised 4% in 1998 and 8% in 2002. The changes occurring over the observation period are indicative of cyclic variations in the structure of this population and its gradual transition from a young into a mature state with subsequent rejuvenation. Vegetative reproduction is of considerable importance in its life.

Cypripedium calceolus is a brevirhizomatous herbaceous perennial plant. The size of the local population varied in the observation period from 5000 to 5150 individuals at a density of 250 to 300 individuals per 0.25 ha. The population was normal, incomplete in the first two years (without senile individuals) and complete in subsequent years. Its age spectrum in the first two years was generatively oriented (the proportion of generative individuals was 67 and 63% respectively). A slight prevalence of vegetative individuals (58%) was observed in 1998, and this coincided with the appearance of senile individuals (10%). A sharp increase in the proportion of generative plants (79%), mostly young and middle-aged, occurred in 2002, with the proportion of senile plants increasing up to 22%. A prominent peak of generative individuals in the last year of



Structure and dynamics of orchid populations.

Fig. 1. Age groups of individuals: (j) juvenile, (im) immature, (vm) mature vegetative, (g_1) young generative, (g_2) middle-aged generative, (g_3) old generative, and (s) senile.

observation occurred as the result of transition of many mature vegetative plants into the generative state.

Cypripedium macranthon is a brevirhizomatous herbaceous perennial plant. The size of the local population was 500–550 individuals at a density of 50–120 individuals per 0.25 ha. The population was normal, incomplete in the first year of observation (senile individuals were absent) and complete in subsequent years. Its age spectrum in the first two years (1992 and 1996) was generatively oriented. In 2002, orientation changed to vegetative: the proportion of mature vegetative individuals sharply increased (50% of total particula number). Juvenile individuals were absent in 2002. This was probably due to unfavorable weather conditions in the previous year: the underground plantules could die off or be retarded in development, remaining at the same stage of ontogeny.

Cypripedium ventricosum is a brevirhizomatous herbaceous perennial plant. Some authors consider it to be a natural hybrid of *C. calceolus* and *C. macranthon.*

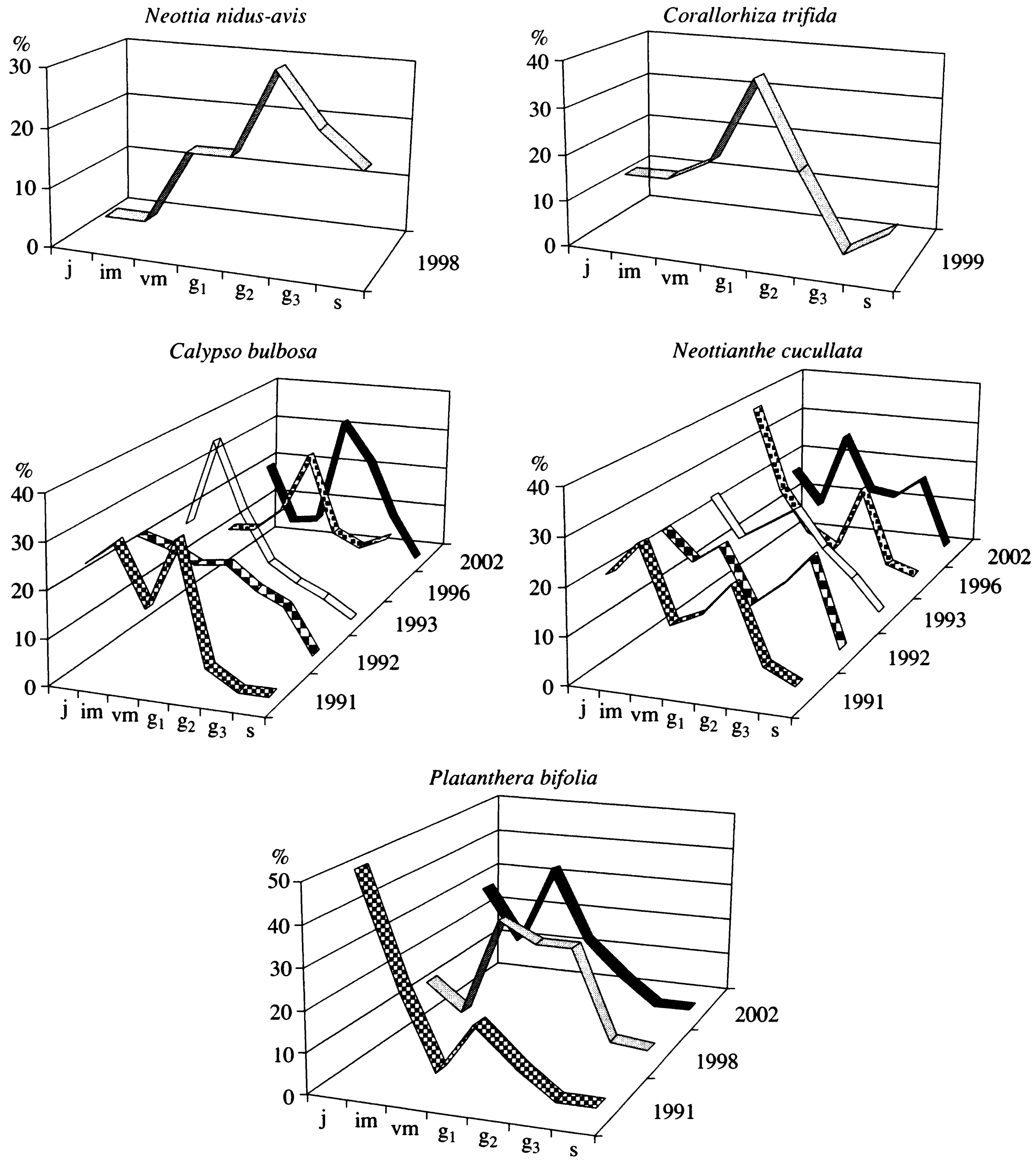


Fig. 1. (Contd.)

The size of the local population varied in different years from 500 to 1000 individuals at a density of 60–100 individuals per 0.25 ha. The population was normal, incomplete because of the absence of senile individuals in 1992 and 1999, and juvenile individuals in 2002. Its age spectrum remained generatively oriented throughout the observation period: the proportion of generative individuals was 68% in 1992, 65% in 1999, and 48% in 2002. A slight decrease in this proportion was accompanied by a pronounced increase in the proportion of mature vegetative particulas (23%) and transition of some generative individuals into the senile state. The absence of juvenile individuals in 2002 was probably explained by the same factors as in the previous species.

Listera ovata is a brevirhizomatous herbaceous perennial plant. The population was small (40–60 individuals at a density of 6–10 individuals per 0.25 ha), normal, and incomplete: juvenile, old generative, and senile individuals were absent in the year of observation. Its age spectrum was bimodal, with one peak accounted for by vegetative individuals (immature and mature vegetative, 50%), and the other, by generative individuals (50%).

Goodiera repens is a creeping-rhizomatous herbaceous perennial. This is a wintergreen plant, i.e., it overwinters with green leaves, which continue functioning in the beginning of the next growing period until the emergence of new leaf generation. Tatarenko (1996) erroneously classified it with evergreen plants. The number of individuals in this population was about 200–300. The plants grew in clumps (clones), where their density reached 140–220 individuals per 0.25 ha. The population was normal and complete. Its spectrum was generatively oriented (53% of generative individuals), with a relatively large proportion of mature vegetative individuals (27%).

Neottia nidus-avis is an achlorophyllous brevirhizomatous herbaceous perennial with storage roots. The local population was small (about 40 individuals), normal, and complete. Its spectrum was generatively oriented (66% of generative individuals) and unimodal. The total proportion of vegetative individuals was 19%, with the prevalence of mature vegetative plants (15%). The group of senile plants comprised 15% of the total population.

Corallorhiza trifida is an achlorophyllous coralloid-rhizomatous herbaceous perennial. The population was small (20–30 individuals), normal, and incomplete (old generative individuals were absent). The population spectrum was generatively oriented (53% of generative individuals).

Calypso bulbosa, a brevirhizomatous-bulbotuberiferous herbaceous perennial, is a wintergreen plant. The leaf of the current year overwinters and continues functioning in the beginning of the next growing period until the appearance of a new leaf. Vegetative reproduction of this plants proceeds via the development of several (usually two) innovation buds on the underground storage organ—bulbotuber (pseudobulb)—of the last season. An additional innovation bud sometimes develops on the bulbotuber of the previous season. In single cases, vegetative reproduction occurs in two successive years, resulting in the appearance of a clone consisting of three or four individuals (Vinogradova, 1998).

Kulikov (1997) considers it impossible to separate generative individuals of *C. bulbosa* into age subgroups (g_1, g_2, and g_3) on the basis of morphological characters. However, slight differences in these characters do exist, and this allows us to distinguish (although somewhat arbitrarily) the subgroups of generative individuals in this species.

The local *C. bulbosa* population was large (1000–1100 individuals at a density of 100–240 individuals per 0.25 ha), normal, and incomplete (senile and, less frequently, old generative individuals were absent). Its spectrum was extremely labile and changed considerably from year to year: it was vegetatively oriented in 1991, 1992, and 1993 (66, 59, and 78% of vegetative individuals, respectively, with a large proportion of immature plants), with its orientation changing to generative in 1996 and 2002 (51 and 67% of generative individuals, respectively).

Neottianthe cucullata is a tuberous herbaceous perennial. This is a vegetatively mobile plant that can move via the formation of a spherical caulorrhizous tuber on a short stolon. The large local population (8000–8500 individuals) had a density of 200–360 individuals per 0.25 ha due to active vegetative reproduction. This population was normal and complete. Its spectrum was stable and vegetatively oriented throughout the observation period (53–67% of vegetative individuals).

Platanthera bifolia is a tuberous herbaceous perennial. Serebryakov (1962) classifies it with tuberrhizous plants and regards its underground formations as tubers developing from stem-producing roots that are formed on short rhizomes (connate roots). Aver'yanova (1991) considers that these underground formations are caulorrhizous tubers that appear as thickened additional roots grow together with the shoot base. Similar to the previous species, *P. bifolia* belongs to vegetatively mobile plants; its caulorrhizous tuber is thickened and fusiform. The number of individuals in the population was 200–250 at a density of 90–140 individuals per 0.25 ha. The population was of an invasive type in the first year of observation (1991) and normal in the subsequent years, being mainly incomplete because of the absent of old generative and senile individuals. Its age spectrum was labile: vegetatively oriented in 1991 and 2002 (the proportion of vegetative individuals in both years was 77%) and generatively oriented (52% of generative individuals) in 1998. This is evidence for alternation of the periods of intense seed and vegetative reproduction.

CONCLUSIONS

In the unique accumulation of orchids in the Middle Urals, the most abundant populations (from 500 to 8500 individuals) are characteristic of the longirhizomatous and brevirhizomatous species *Cypripedium guttatum, C. calceolus, C. macranthon*, and *C. ventricosum*, brevirhizomatous-bulbotuberiferous *Calypso bulbosa*, and tuberous *Neottianthe cucullata*. Medium-size populations are typical of the creeping-rhizomatous species *Goodyera repens* and tuberous *Platanthera bifolia*. The smallest populations (20–60 individuals) are formed by the brevirhizomatous *Listera ovata* and achlorophyllous *Neottia nidus-avis* and *Corallorhiza trifida*.

The populations of these species are subject to wavelike variation in the age structure and density, which is determined both by regular transition of individuals from one age class to another and by weather conditions. The number of generative individuals largely depends on weather conditions in the first part of the previous summer, when generative buds are established. If the weather in this period is warm and moderately moist, relatively large numbers of generative individuals appear in the next summer in species of the genus *Cypripedium* and in *Platanthera bifolia* and *Neottianthe cucullata*. The numbers of flowering individuals formed after a cool and rainy summer are significantly smaller. A snowfall in late May or early June results in a failure to form fruits in *Calypso bulbosa* (because of insufficient number of pollinating insects), as well as in damage to leaves and peduncles in other orchid species.

The species of the family Orchidaceae are sensitive to anthropogenic changes in the environment. In addition to climatic conditions, their abundance largely depends on anthropogenic factors, such as destruction of habitats, grazing load, hay harvesting, recreation, collecting berries and mushrooms, and changes in the tree layer density resulting from felling.

Adaptation to vegetative reproduction and its alternation with seed reproduction allow many orchid species to retain their positions in plant communities for a long time, unless the anthropogenic impact exceeds the critical level.

Environmental conditions in the region of Mount Granatovaya in the Middle Urals are very favorable for the growth of many orchid species, so that their population can exist and successfully reproduce at the present-day level of anthropogenic pressure. The species harmoniously combining seed and vegetative reproduction succeed in reaching the highest abundance. The age structure of populations studied indicates that they are in dynamic equilibrium with the environment. The unique accumulation of orchid populations in the Middle Urals deserves protection and further investigation.

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