J. Eur. Orch.
46 (1): 123 – 160. 2014.

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Orchids as indicator species of forest disturbances on limestone quarry in Georgia (South Caucasus)

Keywords
Orchidaceae; degraded forest, South Caucasus, Georgia, limestone quarry, primary forest, orchids, secondary steppe, shibliak, sky exposition, species density, species fertility.

Summary
Akhalkatsi, M., Arabuli, G. & R. Lorenz (2014): Orchids as indicator species of forest disturbances on limestone quarry in Georgia (South Caucasus).- J. Eur. Orch. 46 (1): 123-160.
Orchids as indicator species are adapted to abiotic factors of habitat and have symbiotic relation with soil mycorrhizal fungi and pollination mechanisms by insects. Sky exposition is lower in degraded forest as high trees are replaced by small trees and shrubs with many twigs covering underground. Intensive cut down changes forest for shibliak containing some short trees and shrubs and having higher sky exposition. Clear cutting and grazing lead to dry secondary steppe.

Sky exposition reveals negative linear correlation (r = -0.767) with species density and degraded forest contains more orchid individuals in shaded understory supporting mycorrhizal fungi conservation in soil. Positive linear correlation was found between fertility and sky exposition (r = 0.412) and orchids are flowering in primary forest with high vertical structure with old-growing trees. Cutting forest shows negative impact on not flowering orchid populations as pollinator bees activity is depending on the density and height of the surrounding vegetation. Shibliak with open canopy contains few species and individuals of orchids. Orchids are absent in secondary steppes due to change of soil composition by influence of high illumination and grazing. Primary forest contains many rare and endemic species. Thus, conservation of orchids needs correct management of habitats protection.

Zusammenfassung

Akhalkatsi, M., Arabuli, G. & R. Lorenz (2014): Orchideen als Indikatoren für die Beeinträchtigung von Wäldern in der Umgebung von Kalk-Steinbrüchen in Georgien (Süd-Kaukasus).- J. Eur. Orch. 46 (1): 123-160.

Aus Georgien wird über die Auswirkungen von Kalk-Steinbrüchen auf die umgebenden Wälder und ihre Flora, insbesondere auf wildwachsende Orchideen berichtet. Erdorchideen gelten als empfindliche Indikatoren für die Naturnähe ihrer Habitate, da sie einerseits stark an die abiotischen Faktoren ihres Habitats angepasst sind, andererseits in Symbiose mit den Mykorrhiza-Pilzen des Bodens leben und enge, oft sehr spezifische Beziehungen zu ihren Bestäuber-Insekten besitzen. Für Arten, die Wälder und Gebüschformationen als Habitate bevorzugen, ist für ihr Fortkommen der Lichteinfall auf den Boden und damit der Öffnungsgrad der Kronendächer (Himmelsexposition) von großer Bedeutung.

Die Entfernung hoher Bäume aus naturnahen alten Wäldern (PF) fördert das Aufkommen von niedrigem Gehölz und Gebüsch (DF) und führt wegen der dichter angeordneten belaubten Äste und Zweige zu stärkerer Beschattung und reduziertem Lichteinfall am Boden. Bei stärkerem Waldeinschlag hingegen wird dieser in offene Shibliak-Gebüschformationen (SH) überführt, der Lichteinfall am Boden erhöht sich dadurch (Fig. 11-14). Kahlschlag von degradierten Wäldern (DF) und darauf folgende Beweidung führen zu trockenen sekundären Grassteppen.

Zur Abschätzung der Artendichte und Fertilität der Orchideenvorkommen in Primärwäldern im Vergleich zu mehr oder weniger degradierten Waldhabitaten wurden vier hierzu geeignete Waldtypen in Kacheti (Ost-Georgien) ausgewählt und mittels populationsökologischer Methoden unter Berücksichtigung der Kronendachöffnung untersucht:

1. Primärer Eichen-Hainbuchen-Wald bei Nekresi in Kacheti (PF) am Südabhang des Großen Kaukasus (Fig. 21),

sowie degradierte Habitate in der Umgebung der Kalk-Steinbrüche von Dedoplistskaro in Kakheti,

2. Degradierte Eichen-Hainbuchen-Wälder (DF, Fig. 20),
3. Shibliak als sekundäres Buschland (SH, Fig. 19),
4. Sekundäre trockene Grassteppen auf Kalk (SS, Fig. 18).

In jedem Habitattyp wurden für das Monitoring der mit Orchideen besetzten Flächen jeweils 20 quadratische Probeflächen von 1m² Größe ausgewählt (Fig. 15-16). Die folgenden Parameter wurden einmal zur Blütezeit und einmal zur Fruchtreife untersucht und dokumentiert:

1. Nummer der Untersuchungsfläche, Lokalität und exakte geographische Koordinaten mit GPS (WGS84), Abbildungen, verwendete Karte, Datum der Geländearbeit,
2. Physikalische Eigenschaften des Orchideenhabitats: Exposition, Geländeneigung (Grad), Meereshöhe (m ü.d.M.),
3. Charakteristika der Pflanzengesellschaften: Deckungsgrad der Vegetation (%) und Höhe des Kronendachs (m); Artenzahlen für die vorhandenen Lebensformen (Bäume, Gebüsch, Süßgräser, Stauden, Riedgräser, Parasiten, Kletterpflanzen, Farne),
4. Anzahl Orchideenarten und Anzahl Individuen jeder Art als Indikatoren der Artenvielfalt,
5. Vitalität und Fertilität der einzelnen Orchideenarten,
6. Hauptgefährdungsursachen für das Habitat und die Indikator-Arten

Der Zustand aller Untersuchungsflächen wurde dabei fotografisch in immer gleicher Art und Weise dokumentiert.

Aus den Untersuchungen ergibt sich eine negative lineare Korrelation mit der Artendichte ($r = -0.767$). In degradierten Wäldern werden im beschatteten Unterholz mehr Orchideenindividuen angetroffen als auf freien Flächen, da hier die Entwicklung der Mykorrhiza-Pilze im Boden begünstigt wird. Eine positive lineare Korrelation wurde zwischen Fertilität und Himmelsexposition gefunden ($r = 0.412$), in Primärwäldern mit hohen und alten Bäumen kommen Orchideen häufiger zum Blühen.

Waldeinschlag reduziert den Anteil blühender Pflanzen in diesen Orchideenpopulationen, da die Aktivität der Bestäuberbienen von Dichte und Höhe der umgebenden Vegetation abhängt. In Shibliak-Habitaten mit offenem Kronendach werden sowohl weniger Orchideenarten als auch weniger Individuen angetroffen. Wegen der negativen Beeinflussung der Bodeneigenschaften durch erhöhte Sonneneinstrahlung und Beweidung sind Sekundärsteppen nahezu orchideenfrei. In Primärwäldern hingegen werden viele seltene und endemische Arten angetroffen. Daraus ergibt sich die Notwendigkeit eines korrekten, d.h. eines die ökologischen Faktoren berücksichtigenden Managements der Habitate, um die darin wachsenden Orchideen nachhaltig zu sichern.

*   *   *

1. Introduction

Orchids are considered as indicator species of habitat disturbances (ROSE 1999). The sensitivity to the habitat conditions of orchid species is determining to both abiotic environmental variables, such as climate, weather, topography and soils (LANDSBERG & CROWLEY 2004) and by their symbiotic relation with soil mycorrhizal fungi and specific pollination mechanisms by insects (HUTCHINGS 2010). Orchid seeds cannot germinate and develop in the wild without the appropriate mycorrhizal fungi, which involves the reciprocal transfer of carbon, nitrogen, and other nutrients between a seedling and its fungal partners (RASMUSSEN 1995, SMITH & READ 2008). Mature orchids remain depending on their mycorrhizal fungi during the periods of growth and reproduction (BUNCH et al. 2013). Therefore, orchids are associated to the fungi in nature and they are depending on habitat conditions supporting micorrhizal fungi conservation in soil composition (WESTON et al. 2005). The distribution of soil fungi in concrete habitat is related to spatial variation in pH and the availability of carbohydrates, nitrogen and phosphorus (KIERS et al. 2011). The disturbances of habitat conditions affect soil composition and forest degradation might be the factor of changes of soil chemistry selecting a suite of fungi that drives the distribution of orchid fungal associations across landscapes (WOLFE & KLIRONOMOS 2005). Thus, forest degradation changing vertical structure of habitat may be correlated in the soil environment changes and orchids will represent as indicators of changes with fungal association.

On the other hand, orchids are depending on pollination environment impacted by human activity and habitat disturbances as their pollination occurs mainly by insects (PAULUS 2005). The negative impact on selection of floral traits may differ between symptoms affecting pollinator attraction and traits affecting pollination efficiency (SLETVOLD et al. 2013). Different pollinator species are thought to have different habitat requirements, possibly based on differences in their choice of nectar and pollen plants, volatile sources or nesting sites (DRESSLER 1990). Orchid bees are native to forests, which are suffering substantial rates of deforestation representing climate change impacts (ZIMMERMANN et al. 2011). Pollinators have visual display of inflorescence height and flower size of orchid species (COZZOLINO & WIDMER 2005). However, insect activity is depending on the density and height of the surrounding vegetation. Therefore, forest cutting and change of vertical structure of habitat indicates that this effect is weaker for traits affecting pollination efficiency (SCADE et al. 2006). The conservation of orchid plants from this point of view is fully depending on existence of these two different living organisms – fungi and pollinators, disappearance of which will cause extinction of rare and extremely high decorative and medicinal species of orchids.

Georgia is one of the countries of the Caucasus ecoregion rich in orchids (AKHALKATSI et al. 2005). Twenty genera and almost 57 terrestrial species belonging to the Orchidaceae family have been determined in Georgia's 69,700 kilometres^2 between 40º and 47º latitude east, and 42º and 44º longitude north (AKHALKATSI et al. 2007; LORENZ 2008). Orchids are distributed in many different habitats in Georgia characterized by an extremely varied topography and climate that produce a mosaic of habitat types ranging from sea level up to alpine vegetation near the snowline; and, from warm, humid lowlands at the Black Sea to dry, continental areas in the Eastern Georgia covered by forests of different types, secondary steppes, and semi-deserts. Two thirds of the country is mountainous area with an average height of 1,200 meter above sea-level (m a.s.l.), with highest peaks of Mount Shkhara (5,184 m a.s.l.) at the Western Greater Caucasus and Mount Didi Abuli (3,301 m a.s.l.) in the Lesser Caucasus. Therefore, climate is temperate but fluctuates by elevation changed on the average of 0.65 °C per 100 m altitude.

Annual precipitation of humidity varies from 1500-2000 millimetres (mm) in Western Georgia and up to 4500 mm in Adjara subtropical area to 400-600 mm to arid zones in the Iori Plateau of Eastern Georgia and in other drier parts of eastern and southern Georgian regions (NEIDZE 2003). About 50 soil types have been described on the territory of the Georgia oriented on complex bioclimatic and different litho logical and geomorphologic conditions (URUSHADZE 1999). Georgian vegetation is well studied by Georgian botanists (GROSSHEIM et al. 1928; KETSKHOVELI 1959; DOLUKHANOV 2010; NAKHUTSRISHVILI 2013). According to these data, 4,400 species of vascular plants, including 380 endemic species, occur in Georgia. One third of the Georgian territory is covered by forests, 70% of which are mountain forests spread from lower montane belt up to the treeline ecotone. According to DOLUKHANOV (2010), the Caucasus forest belt can be subdivided into three major elevation zones: broad-leaved forests (50-900 m a.s.l.), coniferous mixed forests (900-1700 m a.s.l.), and high mountain krummholz forests (1700-2000 m a.s.l.). The overstory is frequently dominated by oak, hornbeam, beech, chestnut, and fir.

Terrestrial orchid species of Georgia are adapted to a great variety of habitats such as shrubbery or wetlands, alpine meadows or open woodlands and even forests (AKHALKATSI et al. 2006). They preferably occur on calcareous soils even in forests covering limestone sediment areas in West and East Georgia. Vegetation of limestone rock is found mainly in the Western Caucasus from Abkhazia including Racha (NAKHUTSRISHVILI 2013). A very interesting community of limestone rock massif is in Javakheti, on the Chobareti mountain range, plateau of Tetrobi, which is recognized as a protected territory

(AKHALKATSI et al. 2009). In Eastern Georgia, there are just small locations of limestone rocks in Kartli and Kakheti. In Kiziki it is located in the surrounding of Dedoplistskaro and in Kakheti in Kvareli district near v. Shilda.

Therefore, the investigation of forest habitat disturbances on calcareous habitats rich in orchids and other geophytes is of high importance (PIQUERAY et al. 2007). Almost all native orchid species distributed in Georgia are threatened due to extreme anthropogenic impacts. The major negative factors leading to the habitat destruction and in such a way endangering orchid species by the extreme reduction of the number of individuals within the populations and causing their extinction are overgrazing, plant collecting in undisturbed habitats, pollution, road and pipeline constructions, deforestation, land degradation, urbanization, climate change, etc. (AKHALKATSI et al. 2003).

Destruction of calcareous habitats is strongly connected with limestone quarry mining and extraction of calcareous sediments causing cleaning of vegetation cover and soil. Surrounding area of quarry is under human impacts during quarry handling and changes of habitat structure affect species density and fertility. Main idea of this work was to conduct inventory of plant species and habitat structure to develop recommendations and management principles on conservation of orchids dominated in calcareous plant communities. Habitat with many orchids and other geophytes species was found at the adjacent to Dedoplistskaro limestone quarry region. The operation of this quarry was started in 1954 and is active till today managed by *'HeidelbergCement AG'* since May 2006, which interest contains restoration of habitats after implementation of quarry extraction. Population ecology methodology and sky exposition effect on species density and fertility of orchids in disturbance and natural forest habitats have been used to determine species status and develop recommendations on their conservation.

2. Materials and Methods

2.1. Study area

Four different habitat types of calcareous Oak-Hornbeam forest were selected for an assessment of orchid species diversity and fertility in a fragmented landscape and for comparison of virgin forest with old-growth dominant trees to a highly disturbed limestone quarry landscape that includes degraded cutting oak forest, secondary scrubland arise from cut down forest and dry meadow created by forest clear cutting (Fig. 1A-E). The study sites of disturbed habitats are located in neighbourhood of Dedoplistskaro's limestone quarry (N 41.487°, E 46.111°, 850-930 m a.s.l., NW, inclination <10°). It is located in Kakheti region, historically Kiziki province, near Dedoplistskaro district center on lower montane belt of south-western extremities of Gombori mountain range with highest peak Mt. Chotori (1084 m a.s.l.) located between Rivers Alazani and Iori gorges. Total area of the quarry is 26.7 hectares, 95% is opened (Fig. 1E).

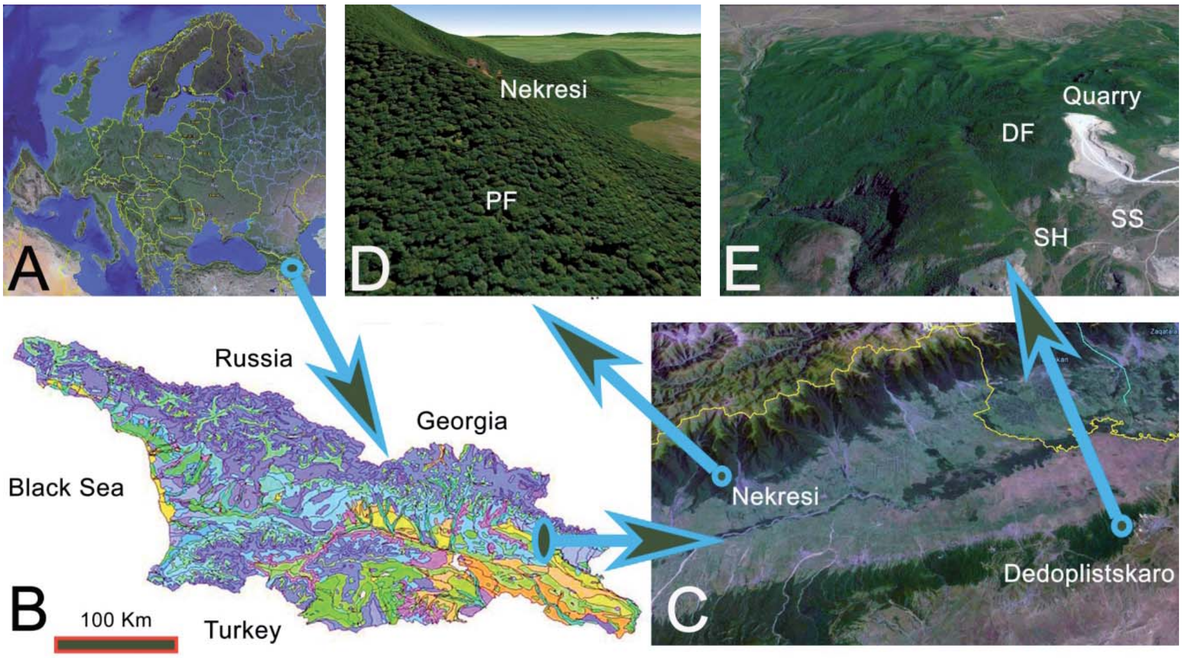


Fig. 1. A- Location of Georgia in the Caucasus; B – Georgian soil map with location of study sites in Kakheti Region; C – Two study sites in Alazani gorge surrounding of Kakheti regions; Nekresi church area and Dedoplistskaro district. D – Nekresi church study site. Oak–Hornbeam primary forest on calcareous sediments (PF); E – Dedoplistskaro limestone quarry with study sites of three habitat types: degraded Oak-Hornbeam forest (DF); Shibliak (SH); Secondary steppe (SS).

Near the quarry is the protected area "Artsivis Kheoba" (N 41.490°, E 46.095°, 721 m a.s.l.), representing climax succession stage of limestone landscape. This area could be interesting for comparison of natural and impacted habitats. However, this forest habitat occurred disturbanced. A suited natural primary forest with the same sediments and soil type was found in Kvareli district, Nekresi Church areas (N 41.975° E 45.763°, 410-970 m a.s.l., NW, inclination >15°) protected historically by religious traditions, where it was not allowed for local Georgian population to use natural resources near churches (Fig. 1D).

The climate in the Kakheti region is dry acutely continental; average annual temperature is 11.2° C, average annual precipitation is 600-1000 mm (MARUASHVILI 1964). Limestone massive located near Dedoplistskaro and Nekresi church is dated from Upper Jurassic period. Geologically it represents part of inter-montane depression. Soil type is the forest brawn-calcareous soils with humus called cinnamonic soils formed on carbonated clayey deposits and containing modern amount of hydrolysable nitrogen and absorbed phosphor, low zinc contents, high boron contents and medium copper and cobalt composition (URUSHADZE 1999). These cinnamonic calcareous soils are characterized by alkaline or strongly alkaline pH (7.95–8.9) and it is low or high carbonated (8.47–37.62%). Natural forest with cinnamonic soil contains more humus (1.31–3.4 %) than arable and ruderal habitats with low content of humus (0.99–2.1 %), showing that the area has been eroded (KORAKHASHVILI et al. 2009).

2.2. Habitat types

The study site near Nekresi church represents natural primary Oak-Hornbeam forest. The same habitat type based on disturbed plant communities were identified in the study site near Dedoplistskaro's limestone quarry: 1. Degraded Oak-Hornbeam forest; 2. Dry secondary scrubland – Shibliak; 3. Dry grazing land - secondary steppes on calcareous rocks.

2.2.1 Oak-Hornbeam forest: Oak forests in Georgia are mainly created by two species (NAKHUTSRISHVILI 2013) – the Georgian oak (*Quercus iberica*) and high mountain oak (*Q. macranthera*). Other oak species - *Q. pedunculiflora, Q. hartwissiana, Q. imeretina, Q. pontica, Q. dshorochensis,* are mixed with other species in the forests of a different type, such as, Kolkhic mixed forest (*Q. hartwissiana, Q. pontica, Q. dshorochensis*), or the Riparian forest (*Q. pedunculiflora, Q. imeretina*). The Georgian oak (*Quercus iberica*) forest is widespread in almost all forest regions of Georgia (NAKHUTSRISHVILI 2013). It is not found only in Tusheti, northern Khevsureti and Khevi. It holds about 200 thousand hectares of the area and grows in dry and sometimes limestone soil as in this study site (LACHASHVILI et al. 2007). In Eastern Georgia it is found from 350-500 to 1000-1550 m a.s.l. In Western Georgia it's distributed at the height of 1500-1800 m a.s.l. (Svaneti). The following species can be found together with the oak: *Carpinus caucasica, C. orientalis, Acer laetum, Sorbus torminalis, Zelkova carpinifolia, Ostrya carpinifolia* etc. Oak - Hornbeam forest adjusts the Dedoplistskaro's limestone quarry from northern and western sides. It represents xero-thermophyte Georgian oak (*Quercus iberica*) forest

(LACHASHVILI et al. 2007) mixed with the hornbeam (*Carpinus caucasic*a) and oriental hornbeam (*Carpinus orientalis*). The Hornbeam is represented as well in degraded forest, but in lower amount than in primary Oak-Hornbeam forests. Oak forest with oriental hornbeam is partly in combination with shibliak scrub communities (NAKHUTSRISHVILI 2013). A large number of orchids and other geophytes are occurring in this habitat.

2.2.2 Shibliak: Shibliak is characteristic to the Mediterranean region, but it is widely distributed as well in Georgia (NAKHUTSRISHVILI 2013). It is located mainly in Kartli and Kakheti regions in the colline zone of vegetation on arid hills as small fragments between 200-1000 m a.s.l. (LACHASHVILI et al. 2007). It is under the anthropogenic impact in respect with the road and industrial construction. It is extremely grazed near populated areas. Dominant species are: *Paliurus spina-christi, Berberis vulgaris, Cotynus coggygria, Punica granatum, Spiraea hypericifolia, Crataegus* spp., *Rhamnus palasii* etc.. The shibliak in the study area belongs to secondary scrubland formed due to strong cutting of oak forest. Some orchid species and other geophytes are occurring in this area.

2.2.3 Dry meadow-steppes on calcareous rocks: In the study site, dry meadow-steppe habitats are secondary meadows as openness of forest and shibliak scrubland. This habitat is formed due to anthropogenic impact of oak forest clear cutting and is covered only by grasses, herbs and some geophytes flowering in early spring. Orchids neither are not distributed in this area.

2.3. Study Site Measures

The measured habitat types are:

1. primary Oak-Hornbeam forest (PF) in Nekresi Church areas;
2. Degraded Oak-Hornbeam forest (DF) in the surrounding of limestone quarry in Dedoplistskaro;
3. Shibliak (SH) as secondary scrubland after DF forest cutting; and,
4. Dry meadow-steppes (SS) on calcareous rocks representing secondary steppes of clear cutting DF forest.

The investigation was carried out using methods of plot recording. Preference is given to the square shape of the recording plots. For this purpose 20 plots of size 1 m^2 will be chosen within each habitat types covered by populations of orchid species. The time of inventory will be coincided to two phenological phases in each population at flowering and fruiting stages. For each plot, photos will be taken from fixed points during each visit.

The following parameters will be determined on the base of data collected during field observations:

1. Data for documentation of the record: plot No., location, figure(s), map and date of field material collection, exact GPS coordinates;
2. Physical environmental characters of habitat types of orchid species distribution: exposition, inclination (°), Elevation (m a.s.l.);
3. Plant community characteristics per habitat types: Vegetation cover (%) and canopy height of habitat vertical structure (m); species number of life forms (trees, shrubs, grasses, herbs, sedges, parasites, vines, ferns).
4. Species diversity determined as total number of individuals of an orchid as indicator species in all studied 1 m^2 plots;
5. Overall ecological state of vitality and fertility of indicator orchid species;
6. Main threats impacted the habitat types and indicator species.

Maximum canopy height has been measured in each habitat types in the study sites and basal cover of trees is determined by measuring of trunk diameter at breast height measured for the same trees. Depending on vertical structure were measured height of tree species covered secondary layer of forest and shrubs as determined by life forms. Vegetation canopy cover is measured as the percentage of ground cover by a vertical projection of the understory shrub, herbs, grasses and other species.

Forest light environments were assessed by measuring canopy openness corresponds to sky exposition and means open sky area in the forest upper floor. This value has been calculated using fish-eye lens attached on digital camera Nikon CoolPix 5500. The photos of area 180° have been taken above research plots. The data showed percentage of open area in the 180° ambient.

Density of orchid species determined as the number of individuals has been calculated of all orchid species per unit area ($1m^2$) in May and June for different species. The equation used is: $D = n / A$. ('n' is number of individuals of all orchid species in one unit area; 'A' is plot size $1m^2$). Second measurement was done for species fertility in the same 20 plots and have been accounted at each research sites. Fertility was determined as number of flowering individuals of orchid species in the same plot where species density is calculated.

2.4 Data analyses

To compare environmental data of habitat types, vegetation cover and canopy height is used one-way ANOVA ($p<0,05$). To test spatial autocorrelation in two habitat types of primary and degraded oak forest vegetation (sky exposition and species density and fertility) the software package SPSS v.16 has been used.

The calculation of sky exposition was done using digital images were imported into Gap Light Analyzer software (Version 2.0, Simon Fraser University, Burnaby, British Columbia, Canada, and Institute of Ecosystem Studies, Millbrook, New York, U.S.A.) and used to calculate the fraction of the hemispherical image not obscured by objects (i.e. percent sky exposition).

A Detrended Correspondence Analysis (DCA) was performed to demonstrate relationships between species distribution and environmental conditions among plots of habitat types. Environmental data: habitat types, inclination, elevation, vegetation cover, height of trees, secondary layer trees, shrubs and herbs, sky exposition, orchid species density and fertility and summary data of species composition were determined as important 16 characters for the differences in habitat types during conducting a principal components analysis (PCA) based on correlation matrix.

The analyses were performed using Statistics 16.0, PC-ORD 5.33 and Statistica 6.0.

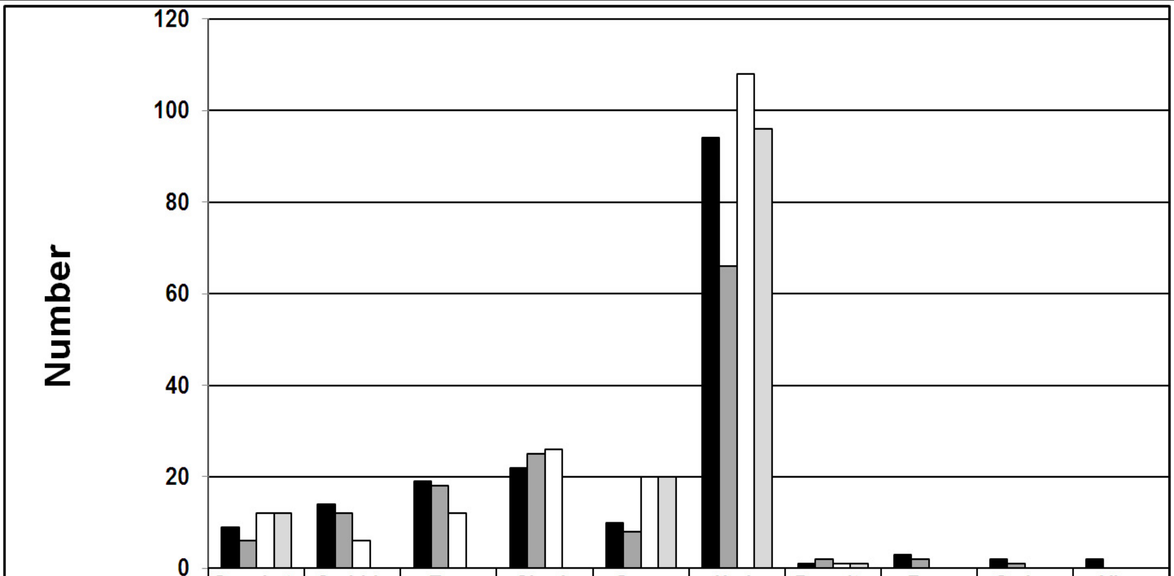
3. Results

3.1. Comparison of the species composition

Total number of vascular plants in the studied areas achieved 267 species (Table 1, **see Annex 1**). Number of species according to life forms is following: orchids 15, other geophytes 17, overstory trees representing the uppermost canopy layer of a forest formed by the tallest trees are 20, a substantial understory of shrubs and small trees 30, sedges 2, grasses 25, herbs 151, parasites 2, ferns 3 and vines 2 species (Fig. 2).

The species of vascular plants have been determined in 4 studied habitat types:

3.1.1 Primary Oak - Hornbeam forest (PF) near Nekresi church area is covered by oak mixed deciduous forest, with 176 species of vascular plants (Fig. 2, 3). Overstory canopy trees are 19 species: *Quercus iberica, Carpinus caucasica, C. orientalis, Celtis caucasica, Cydonia oblonga, Acer campestre, A. laetum, Fraxinus excelsior, Fagus orientalis, Ficus carica, Malus orientalis, Mespilus germanica, Morus alba, Populus tremula, Prunus avium, Pyrus caucasica* (Caucasian endemic), *Robinia pseudoacacia* (invasive), *Tilia begoniifolia*, *Ulmus minor* (Red Data Book - RDB).



	Geophyte	Orchids	Tree	Shrub	Grass	Herb	Parasite	Fern	Sedge	Vine
■ Primary forest	9	14	19	22	10	94	1	3	2	2
■ Degraded forest	6	12	18	25	8	66	2	2	1	0
□ Shibliak	12	6	12	26	20	108	1	0	0	0
□ Secondary steppe	12	0	0	0	20	96	1	0	0	0

Fig. 2. The number of life forms of vascular plant species in study habitat types: primary forest, degraded forest, shibliak and secondary steppe. (N=267).

The secondary layer trees are 7 species – *Cornus mas, Coryllus avellana, Crataegus pentagina, Euonymus europaea, Prunus divaricata, P. mahaleb* and *P. microcarpa* covering only 20% of secondary layer of the forest. Shrubs prevail on forest edges representing 15 species - *Berberis vulgaris, Cotinus coggygria, Cotoneaster morulus, Jasminum fruticans, Lonicera caprifolium, L. caucasica, L. iberica, Pyracantha coccinea, Rhamnus cathartica, Rosa canina, Rubus anatolicus, Sambucus nigra, Spiraea hypericifolia, Swida australis, Viburnum lantana*. Forest understory herbs are 94 species. Very rare herb - *Smyrnium perfoliatum* (Apiaceae) have been found only in this habitat. Sedge represented by 2 species - *Carex sylvatica* and *C. cuspidata.* Grasses are only 10 species. Geophytes are with 14 orchid species (Fig. 4) - *Anacamptis* *pyramidalis, Cephalanthera damasonium, C. longifolia, C. rubra, Epipactis helleborine* subsp. *bithynica, E. persica, E. purpurata* subsp. *kuenkeleana, Limodorum abortivum, Neottia nidus-avis, Ophrys oestrifera* subsp. *oestrifera, O. sphegodes* subsp. *caucasica, O. purpurea* subsp. *caucasica, O. simia, Platanthera chlorantha*; The total number of geophytes is 23 species added to orchids 9 species – *Allium atroviolaceum, A. rotundum, Convallaria transcaucasica, Cyclamen coum* subsp. *caucasicum, Galanthus lagodechianus, Poa bulbosa, P. bulbosa* var. *vivipara, Polygonatum glaberrinum* and *Scilla sibirica.* Parasite is only one species – *Viscum album.* Ferns are 3 species – *Asplenium trichomanes*, *A. adiantum-nigrum* and *Ceterach officinarum*; and, 2 vines - *Hedera pastuchowii* and *Tamus communis* (Fig. 3).

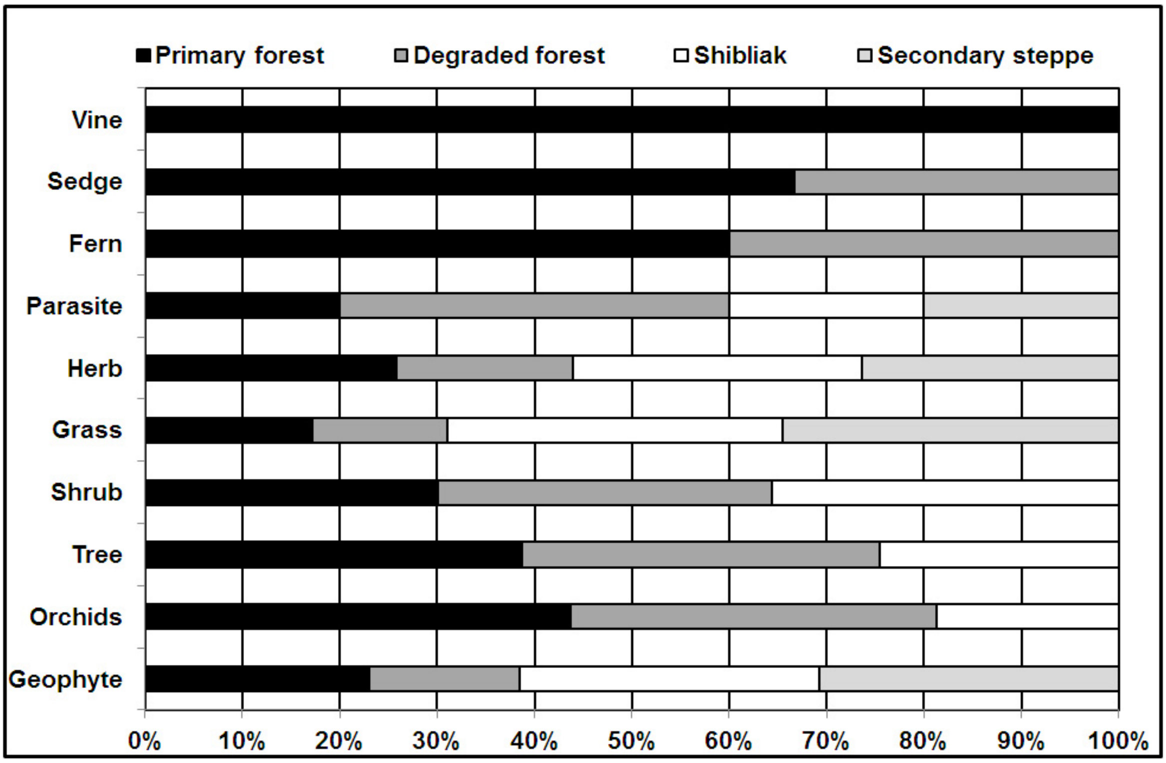
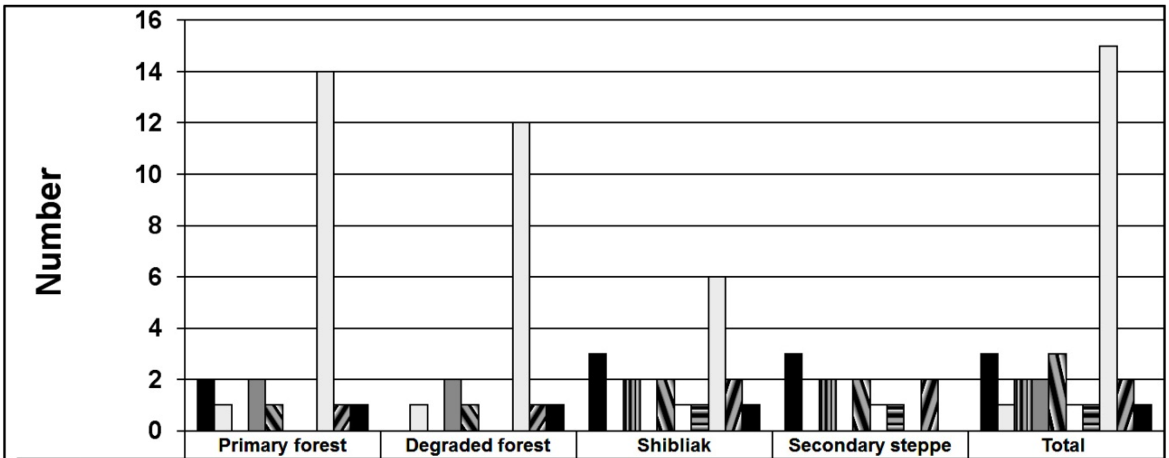


Fig. 3. Percentage distribution of life forms in study habitat types: primary forest, degraded forest, shibliak and secondary steppe. (N=267).

3.1.2 Degraded Oak-Hornbeam forest (DF) is influenced by human impact and overstore canopy trees are mainly cut and the species composition is decreased in comparison with PF to 140 vascular plant species (Fig. 2, 3). Oak trees are very few and shorter. From other trees prevails *Carpinus orientalis.* The hornbeam (*Carpinus caucasica*) is represented as well in this forest, but in lower amount than in typical Oak-Hornbeam forests. Total number of trees is 18 and two species of PF are not found- *Fagus orientalis* and *Ficus carica.* One invasive species is added - *Ailanthus altissima.* The secondary layer trees and shrubs are 25 species with additional 4 species to PF: *Amygdalus incana,* *Cotoneaster integerrimus, Juniperus oblonga, Punica granatum*. *Sambucus nigra* is not found in this habitat. The understory is mainly represented by the herbal and grass cover. Grasses (8) and herbs (66) are very well developed. One species of sedge (*Carex sylvatica*) have been found. Parasites are *Viscum album* and *Orobanche ramosa*. Geophytes are presented only by 18 species in the forest area (Fig. 4). Among them most are orchids (12). Two orchid species - *Epipactis persica* and *E. purpurata* subsp. *kuenkeleana,* from PF are absent. Ferns are 2 species without *Asplenium adiantum-nigrum* found in PF (Fig. 3). Vines are not distributed on small trees in this habitat.



	Primary forest	Degraded forest	Shibliak	Secondary steppe	Total
Alliaceae	2	0	3	3	3
Amaryllidaceae	1	1	0	0	1
Colchicaceae	0	0	2	2	2
Convallariaceae	2	2	0	0	2
Hyacinthaceae	1	1	2	2	3
Iridaceae	0	0	1	1	1
Liliaceae	0	0	1	1	1
Orchidaceae	14	12	6	0	15
Poaceae	1	1	2	2	2
Primulaceae	1	1	1	0	1

Fig. 4. Family and species number of geophytes in study habitat types: primary forest, degraded forest, shibliak and secondary steppe. (N=32).

3.1.3 Shibliak (SH). A total of 185 species has been identified in this habitat type (Fig. 2, 3). Among them are 12 tall trees, 22 small trees and shrubs dominated by *Paliurus spina-christi*, 20 grasses, 108 herbs, 1 parasite - *Orobanche ramosa* and 18 geophytes with 6 orchid species (Fig. 4): *Allium atroviolaceum, A. pseudoflavum, A. rotundum, Anacamptis pyramidalis, Colchicum szovitzii, Crocus adamii, Gagea chanae, Hordeum bulbosum, Merendera trigina, Muscari szovitsianum, M. tenuiflorum, Ophrys oestrifera* subsp. *oestrifera, O. sphegodes* subsp. *caucasica, Orchis morio* subsp. *caucasica, O. purpurea* subsp. *caucasica, O. simia, Poa bulbosa, P. bulbosa* var. *vivipara.* One orchid species - *Orchis morio* subsp. *caucasica* is growing outside of forest only in shibliak habitat. This area is completely empty of ferns, sedges and vines.

3.1.4 Dry meadow – secondary steppes (SS). Total number of plant species is 129 with 20 species of grasses, 96 herbs, one parasite - *Orobanche ramosa* (Fig. 2, 3). Trees and shrubs are completely absent. Geophytes in this area are represented by 12 species especially flowering in the early spring (February-March) adapted to dry meadow-steppes and shibliak areas (Fig. 4) - *Colchicum szovitzii, Crocus adamii, Gagea chanae, Merendera trigina, Muscari szovitsianum, M. tenuiflorum*. Summer flowering geophytes are - *Allium atroviolaceum, A. pseudoflavum, A. rotundum, Hordeum bulbosum, Poa bulbosa, P. bulbosa* var. *vivipara.* Orchids are not found on secondary steppes.

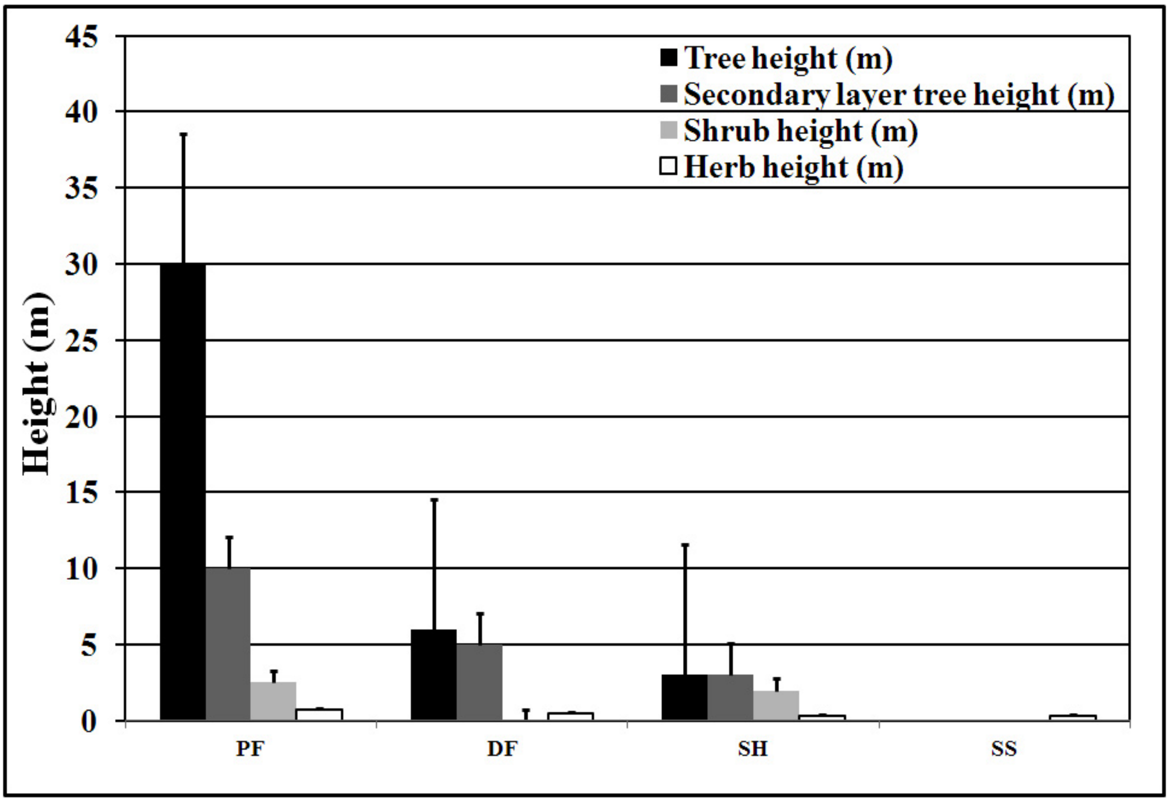


Fig. 5. Mean and standard deviation of habitat vertical structure: overstory tree, secondary layer tree, shrub and herb height (meter) in study habitat types: primary forest (PF), degraded forest (DF), shibliak (SH) and secondary steppe (SS). (N=20).

3.2. Vertical structure of habitats

PF in Nekresi church area has no human impact and maximum tree height of overstory species reach 30-40 m tall (Fig. 5). These were old-growth trees with long diameter of trunks till 0.7-1.2 m. The secondary layer trees are 10-15 m tall with 0.2-0.4 m diameter of trunks. Shrubs rise to 2.5 m and growth preferably on forest edges. The understory herb cover height reaches 70 cm tall.

Anthropogenic impact of studied DF habitat types and shibliak are strongly cutting down and typical structure of forest is strongly changed. They are cutting down not only trees for firewood, but some twigs or even shrubs completely. In DF habitat not any oak tree higher than 5-7 m has been found, all with trunk diameters at maximum 0.2-0.3 m (Fig. 5). These small trees were juvenile trees, which in the future will be cut again. Hornbeam was as well represented by young small individuals and oriental hornbeam was strongly cutting down. Secondary layer trees are almost the same size 4-6 m with basal diameters 0.2-0.3 m. Shrubs rise similar height as in PF and herbs are till 0.5 m.

The effect of tree cut down in shibliak habitat types reduce forest vegetation to scrub and trees of forest secondary layer remain as 3-5 m height of lower number of individuals and shrubs are little lower till 2 m and grass and herbs are as well shorter till 0.3 m (Fig. 5). The SS meadow is lost of trees and shrubs and contains only lower vegetation cover (Fig. 5). Both habitat types SH and SS are under grazing impacts where local cattle grazing is very intensive during the whole year.

3.3. Sky exposition, species density and fertility

Along transects, mean light availability differs significantly between forest habitat types. This has effect on canopy openness in the DF forest as instead of high trees there are small trees and shrubs by many twigs which cover underground much more than it is in normal PF habitat. The comparison of dates in cutting Dedoplistskaro and virgin Nekresi oak forests has revealed important differences in sky exposition (Fig. 6). The sky exposition in cutting DF was lower (8.754±1.758%) than in virgin PF habitat (17.165±5.962 %, Fig. 7). The open areas as scrub and meadow habitats show height value of sky exposition SH (49.4±12.15) and SS (66.62±13.72) covered basically by slope and rock inclinations (Fig. 7). Sky exposition shows highest differences among environmental data of habitat types by ANOVA ($F=22,104$; $p<0.04$).

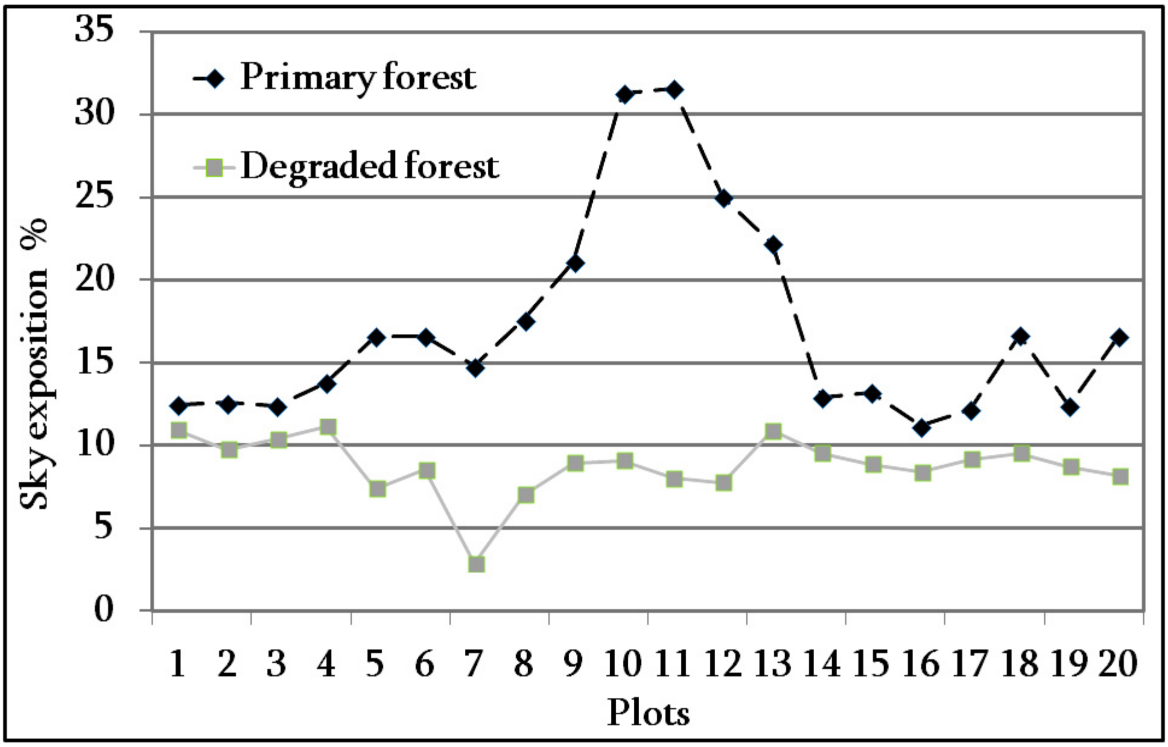


Fig. 6. Sky exposition percentage in primary and degraded forest habitats. (N=20).

The data of species density revealed higher number of individuals of orchid species per research plot in cutting DF (3.1±1.197) and lower number in PF (1.5±0.71; Fig. 7). In May there were the following species of orchids: *Ophrys oestrifera* subsp. *oestrifera, O. sphegodes* subsp. *caucasica, Orchis purpurea* subsp. *caucasica* and *O. simia* flowering in PF in understory and in DF only in forest edges. Understory of DF was covered by orchid individuals without inflorescences and presented as vegetative plants with leaves. The orchid species – *Cephalanthera damasonium* and *C. longifolia* have flowering in DF understory, but in June they did not present fruits and inflorescences remain without seeds. The same results have shown *Epipactis helleborine* subsp. *bithynica* with flowers and no fruits in inflorescence. Therefore, the lower value of fertility (0.5±0.1) was revealed in cutting DF (Fig. 7), where the total number of individuals per plot was higher and percentage of fertility is equal to 16.12±5.8 %. Almost all orchids were flowering and having most of the fruits with seeds in inflorescences in understory of virgin PF showing higher fertility (1.2±0.63; Fig. 7) and the percentage of fertility to existing species density represents 80±9 %.

Negative linear correlation was determined between species density and sky exposition (r = -0.767; Fig. 8). More orchid individuals occurred in cutting forest with lower sky exposition and lower number was found in normal forest.

Positive linear correlation was found between fertility and sky exposition ($r = 0.412$; Fig. 8). As higher is sky exposition as many orchid individuals are in flowering stage.

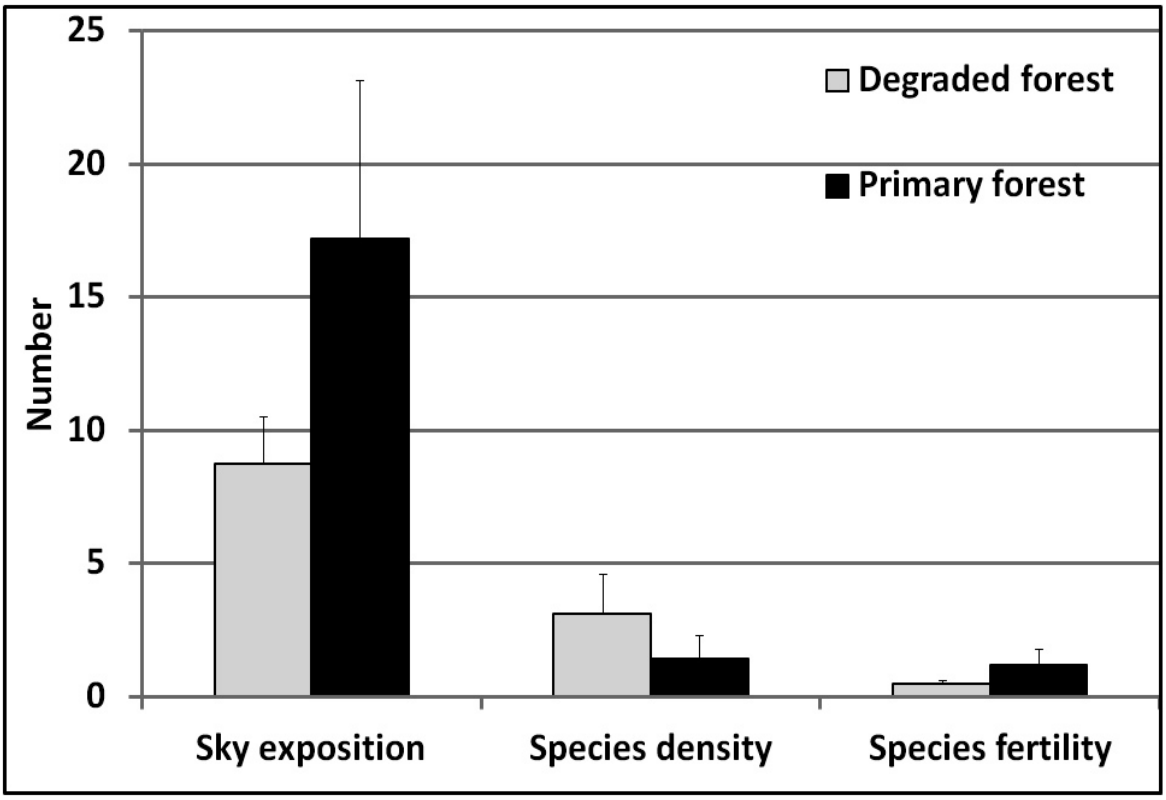


Fig. 7. Mean and standard deviation of sky exposition, orchid species diversity and fertility in primary and degraded forest habitats. (N=20).

3.4. Comparison of habitat types

The DCA analysis was based on cumulative initial eigenvalues of 3 principal components (PCs) reached 100% (63.916%, 20.15%, and 15.934%, respectively). The DCA scatter plot show distribution of the 267 species composition in 4 habitat types (Fig. 9). The PF habitat type is located in the left upper part of the scatter plot and contains tree and herb species located only in this habitat types. Vine and ferns species are only in this habitat. Orchid species - *Epipactis persica* and *E. purpurata* subsp. *kuenkeleana* are included in this habitat type. The other orchid species are located in DF shown on left lower part of the plot. SH and SS are located right lower and upper parts and contain only several herb and grass species.

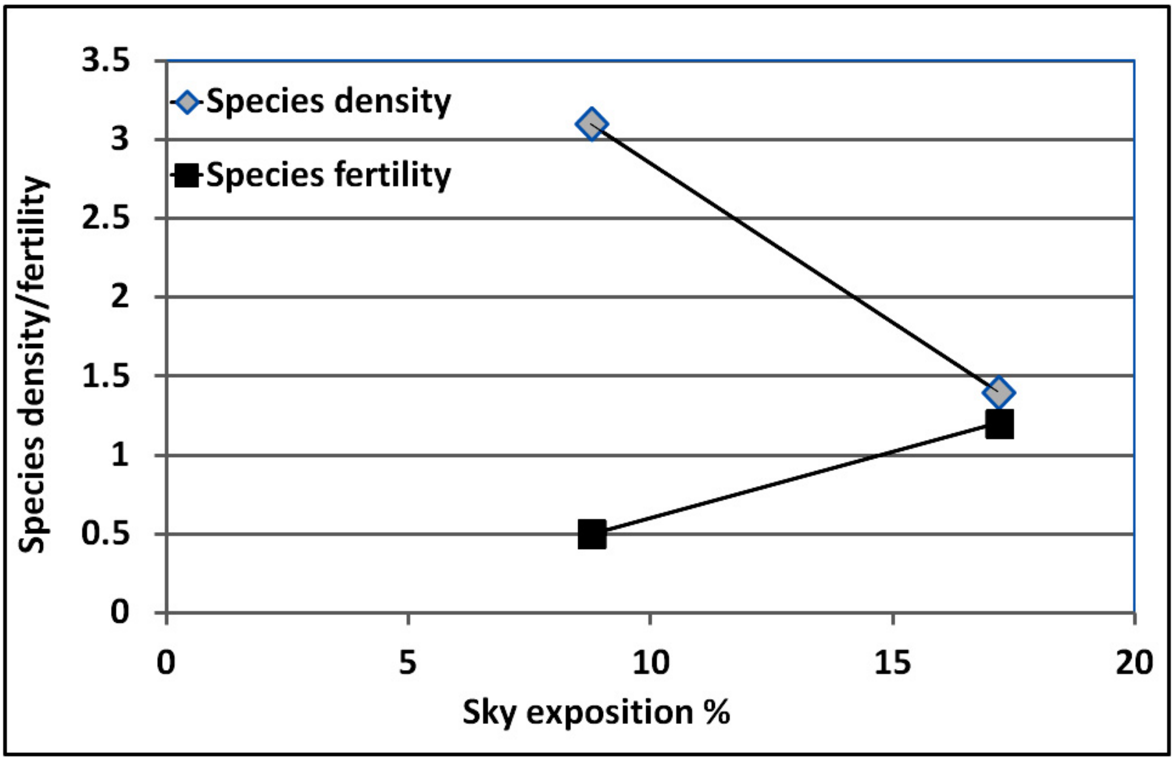


Fig. 8. Relations between sky exposition percentage and mean number species diversity and fertility in two habitat types: primary forest (sky exposition in x axis17.165±5.962%) and degraded forest with sky exposition (8.754±1.758%). The Pearson correlation between sky exposition and species diversity (r = -0.767) and sky exposition and species fertility (r = 0.412).

The distribution of habitat types along the axes was different and it is similar to the distributions of sample plots characters based on 16 ecological indicators (Fig. 10). PF habitat type is again located to left upper part of the plot restricted to the first ordination axes and are positively correlated with the orchid species fertility, tree and herb height, inclination and vegetation cover. DF habitat located in lower left part is depending on the following ecological indices: shrub height and orchid species density. SS and SH are depending only on environmental conditions. Sky exposition is with highest value in these habitat types.

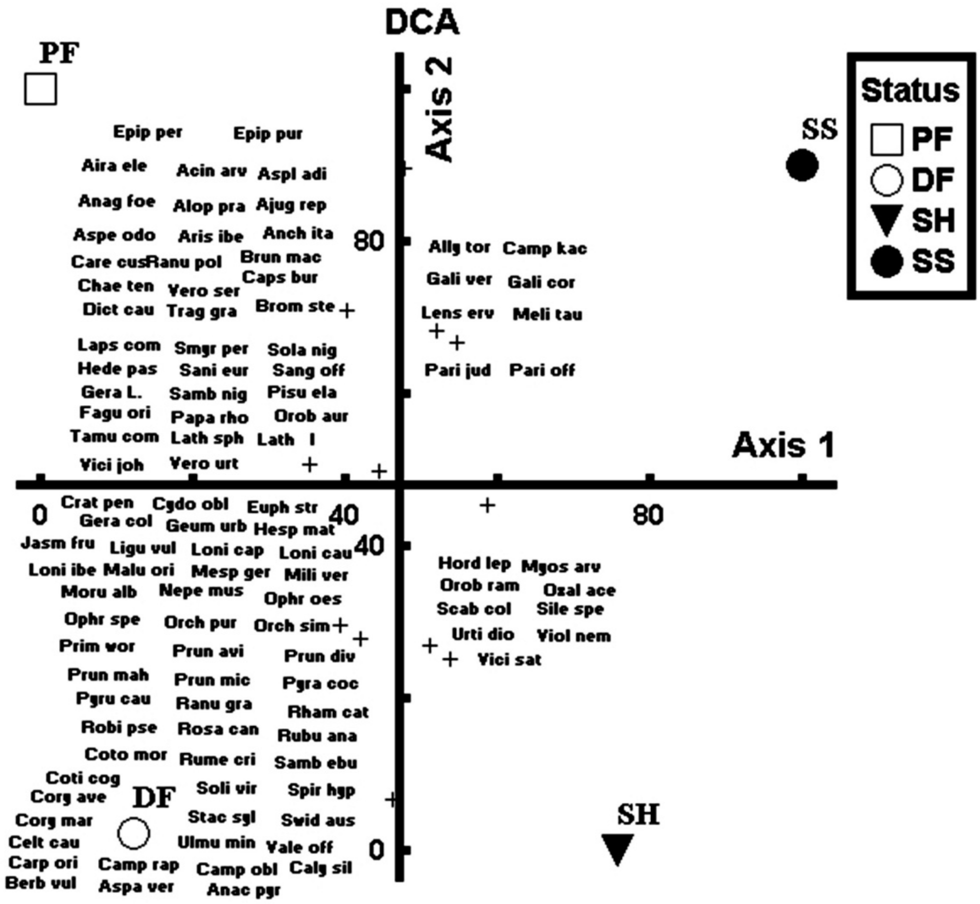


Fig. 9. Detrended correspondence analysis (DCA) diagram showing the ordination of 267 species existence at studied 4 habitat types: primary forest (PF), degraded forest (DF), shibliak (SH) and secondary steppe (SS); in relation with environmental variables of studied sites (species names). (N=267; 16)

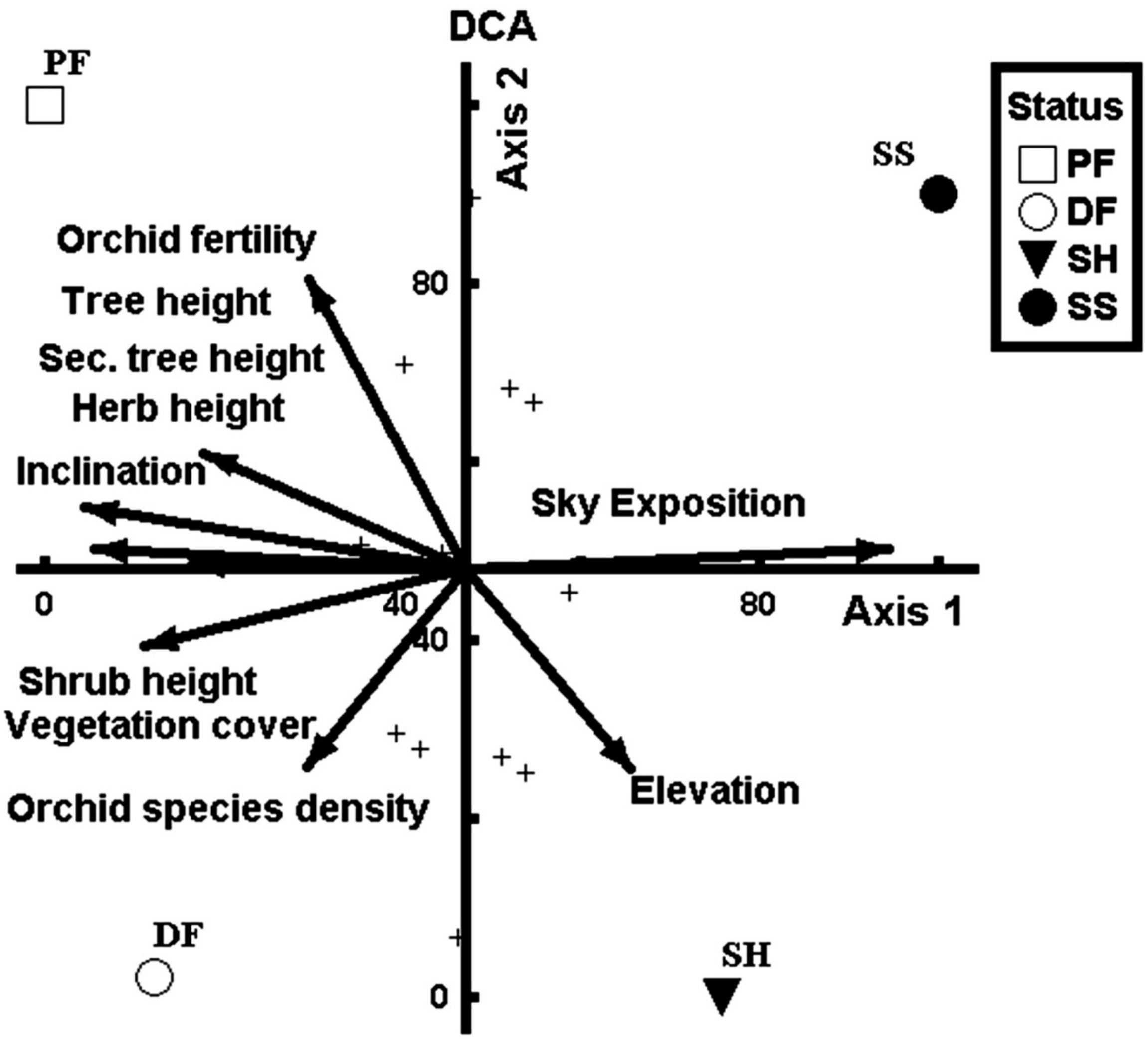


Fig. 10. Detrended correspondence analysis (DCA) diagram showing the ordination of 267 species existence at studied 4 habitat types in relation with environmental variables of studied sites (arrows). The first axis is horizontal, second vertical. The direction and length of arrows show the degree of correlation between habitat types and environmental variables (E. g. PF is positively correlated with species fertility, overstory tree and herb height, inclination and vegetation cover). DF habitat type is correlated with orchid species density and shrub height. (N=267; 16).

4. Discussion

The aim of this work was to compare the indicator orchid species density and fertility to habitat conditions in the virgin primary and disturbed cut down oak forests affected by human impacts and limestone quarry actions (Fig. 7, 8). The primary forest vertical structure contains old-growing height trees and sky exposition more open than in cut down degraded forest, which have lost height trees and sky exposition was decreased by lower secondary layer trees and shrubs covering understory (Fig. 5, 6). The intensively disturbed forest is changed to secondary scrubland - shibliak and clear cutting forest transformed to dry meadow called secondary steppe.

The threats occurring in the adjacent area of Dedoplistskaro limestone quarry can be divided in two directions:

1. threats affected by limestone quarry actions; and,
2. anthropogenic impact of local population on the area, which causes transformation of tall-trees into shrubbery.

The first threat causes the following disturbances:

1) completely removing of green plant cover from the area; and,
2) cover by dust the adjacent vegetation.

Both disturbances have effect on plant diversity. The second anthropogenic impact by local population in this area was identified as strong wood cutting. They are cutting down not only trees for firewood, but some twigs or even shrubs completely for use them for bread baking in clay bakery called 'Tone'. Habitats of degraded oak forest and shibliak near limestone quarry are strongly cutting down and typical structure of forest is strongly changed. In DF habitat not any tall trees have been found (Fig. 5). The small trees were juvenile trees, which in the future will be cut again. Oriental hornbeam trees are cutting very intensively and the image of this tree is changed after cutting to the shrub or has many outgrowths on stem and they are like on topiary exemplars. This has effect on canopy openness and sky exposition in the forest as instead of high trees there are small trees and shrubs by many twigs, which cover underground much more than it is in normal forest (HORSLEY et al. 2008; LAURANCE 2012).

The vegetation of calcareous soil and limestone ground material habitats are characterized by high diversity and highest level of endemism (NAKHUTSRISHVILI 2013). The study area is based on limestone ground material and plants are adapted to these concrete conditions. Therefore, there are many species typical for calcareous soils and limestone areas. Vascular plants, 267 total and 32 geophytes were identified in the study habitats. The data show that habitat disturbances affect on species density and fertility of orchids as indicator species and the reason is indicated as decrease of sky exposition due to wood cutting in forest. Among total 15 orchid species distributed in all study habitats, 12 orchids are presented with higher species density in disturbed DF habitat (Fig. 7). PF habitat contains two more species – - *Epipactis persica* and *E. purpurata* subsp. *kuenkeleana* and all other orchids but the species density is lower. The number of orchids is reduced to 6 in scrub shibliak and completely absent in secondary steppes. Negative linear correlation was determined between species density and sky exposition (Fig. 8). The differences of sky exposition is very different among study habitats (Fig. 6) and DF has lowest sky exposition, which causes shading of forest understory and will support soil humidity and affecting composition of mycorrhizal fungi in the soil (ORS et al. 2010; BUNCH et al. 2013). DF habitat conditions are supporting mycorrhizal fungi conservation in soil conditions and orchid existence is available (WESTON et al. 2005). Intensive cut down forest changed to scrub habitat SH containing some short trees and shrubs and having higher sky exposition shows strong negative impact on the populations of orchids remaining only 6 species. The completely open dry meadow SS illuminated more intensively lost all orchid species. These results confirm the data that habitat conditions supporting mycorrhizal fungi conservation in soil conditions and sky exposition depending on forest vertical structure change is affecting soil composition and changes of soil chemistry selecting a suite of fungi that drives the distribution of orchid fungal associations across landscapes (WESTON et al. 2005; WOLFE & KLIRONOMOS 2005). Thus, forest degradation changing vertical structure of habitat may be correlated in the soil environment changes and orchids will represent as indicators of changes with fungal association. In addition, besides the illumination in SH and SS habitats, grazing should have very intensive effect on soil composition change leading to decrease of humidity and minerals (KIERS et al. 2011).

According to obtained data it is supposed that forest cutting decreasing the sky exposition in the habitat has negative effect on fertility of orchids. In spite of high diversity of orchid species in DF habitat type flowering of orchids was strongly diminishing (Fig. 7). Primary forest has more open sky exposition due to tall old-trees in non-disturbed habitat and orchids are flowering actively and are adapted to microclimate conditions determining their fertility related to conservation of symbiotic relations with pollinator insects and mycorrhizal fungi (KULLA & HUTCHINGS 2006). This result is depending on reduce of sky exposition in DF habitat related to deforestation and leading to decrease of soil illumination resulted by cut down of tall older-growth trees and diminishing of the habitat vertical structure, which adversely affects the fertility of orchid species (HORSLEY et al. 2008; KULA & HUTCHINS 2006). Positive linear correlation was found between fertility and sky exposition (Fig. 8). As open is sky exposition as many orchid individuals are in flowering stage. Cutting down forest shows negative impact on the populations of orchids not flowering as orchid bees are native to forests and activity is depending on the density and height of the surrounding vegetation (ZIMMERMANN et al. 2011; SEATON et al. 2013). The fact that the species density is higher in cutting forest and it might be linked with vegetation propagation of orchids through tubers due to restriction of sexual reproduction (ARDITTI 1992). This fact will negatively affect non-flowering population because of diminishing the gene recombination and increase of clones of the species (SLETVOLD et al. 2013). This will increase threat to species extinction due to restricted genetic diversity in the population due to the vegetative propagation limiting the gene recombination and producing the clonally groups of species that poses a threat to the genetic diversity of the population (ZIMMERMANN et al. 2011). Therefore, forest cutting and change of vertical structure of habitat indicates effect on pollination efficiency.

Thus, it is recommended that during the possible restoration of the area of Dedoplistskaro limestone quarry habitats - degraded Oak-Hornbeam forest, shibliak and open dry meadows, it will be recovered from the early stages of pioneer successions. However, orchids of forest habitats will appear in the area only in case if their natural habitats of shibliak and Oak-Hornbeam forest will be restored. According to obtained data, forest habitat disturbances have strong influence on orchid fertility and population genetic status.

The conclusion is that conservation of threatened orchids needs correct management of their habitats protection. The works should be continued on distribution of rare species and mapping of orchids to reveal the critical habitats threatening survival of these unique plant species.

Acknowledgments

Support was provided by *'HeidelbergCement AG'* program "The Quarry Life Awards" where our project "Environmental Education Program for Biodiversity Conservation during the Rehabilitation Process of Limestone Quarry" was awarded by National contest Georgia - 1st prize in 2012. http://www.quarrylifeaward.com/project/environmental-education-program-biodiversity-conservation-during-rehabilitation-process

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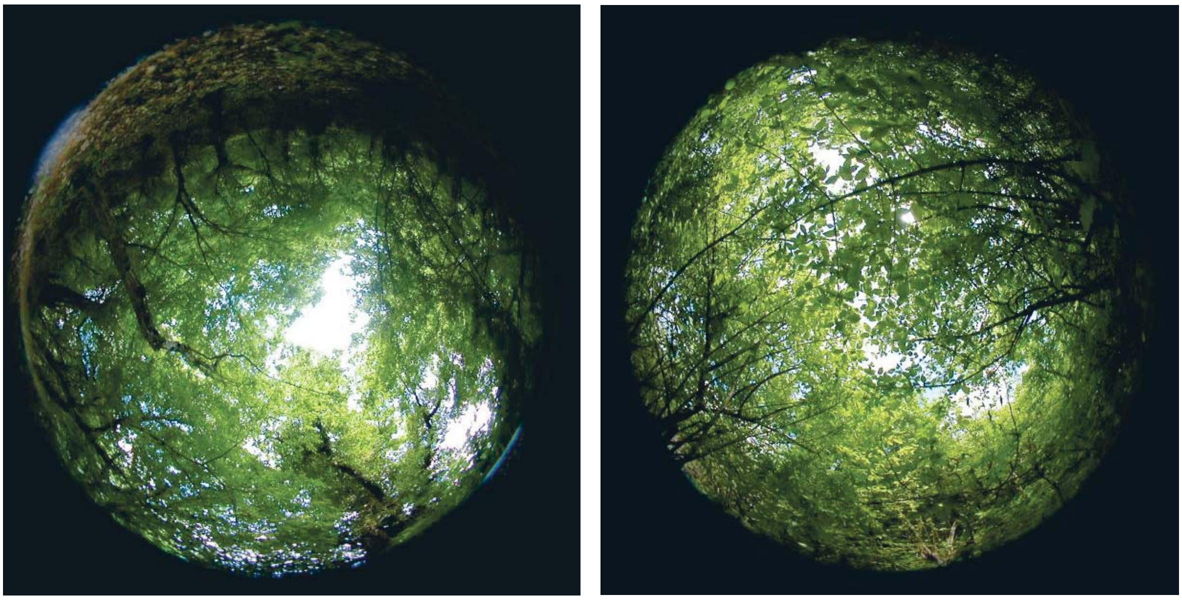

Fig. 11-12: Canopy openness of Oak-Hornbeam forest. Higher sky exposition on fish-eye photo of primary forest (PF) near Nekresi church, (Fig. 11) and lower value in degraded forest (DF) of Dedoplistskaro (Fig. 12), 15.5.2 10, phot. GA.

Fig. 13:-14: Sky exposition in open habitat types of Dedoplistskaro: shibliak (SH; Fig. 13) and secondary steppe (SS; Fig. 14), 15.5.2010, phot. GA.

Fig. 15-16: Field work. Recording plots, Nekresi and Dedoplistskaro, 15.5.2010, phot. GA.

Fig. 17: Part of Dedoplistskaro (Kacheti) limestone quarry and its environment, with degraded Oak-Hornbeam forest (DF); Shibliak (SH); Secondary steppe (SS), 15.5.2010, phot. GA.

Fig. 18: Dry meadow steppes (SS) on calcareous rocks near Dedoplistskaro, (Kacheti), 16.5.2010, phot. MA.

Fig. 19: Shibliak (SH) in colline zone near Dedoplistskaro, (Kacheti), 17.5.2010, phot. MA.

Fig. 20: Degraded Oak Hornbeam forest (DF) near Dedoplistskaro (Kacheti), 24.4.2010, phot. MA.

Fig. 21: Primary Oak Hornbeam forest (PF) with *Tilia begoniifolia* near Nekresi Church (Kacheti), 10.5.2011, phot. MA.

ANNEX 1.

Table 1. List of 267 plant species in indicator orchid species habitats near Nekresi church and *'Heidelbergcement AG'* limestone quarry in Dedoplistskaro. Occurrence of species are indicated for four habitat types: primary Oak-Hornbeam- forest (PF) ; degraded oak-hornbeam forest (DF); dry scrubland - shibliak (SH) and dry meadow- secondary steppe (SS). Rare and endemic species: ● - local endemic; ■ - Caucasian endemic, ▲- Georgian Red List (2006) species; Life forms – tree, secondary layer trees (sec.) trees, shrubs, geophytes, herbs, grasses, sedges, parasites, vines, ferns; Nomenclature by LACHASHVILI et al. 2007; Orchid nomenclature according to AKHALKATSI et al. 2007).

Family	Species	Life form	PF	DF	SH	SS
Aceraceae	*Acer campestre* L.	Tree	1	1	0	0
Aceraceae	*Acer laetum* C. A. Mey.	Tree	1	1	0	0
Alliaceae	*Allium atroviolaceum* Boiss.	Geophytes	1	0	1	1
Alliaceae	*Allium pseudoflavum* Vved.	Geophytes	0	0	1	1
Alliaceae	*Allium rotundum* L.	Geophytes	1	0	1	1
Amaryllidaceae	*Galanthus lagodechianus* Kem.-Nath. ■	Geophytes	1	1	0	0
Apiaceae	*Anthriscus longirostris* Bertol.	Herb	1	1	0	0
Apiaceae	*Chaerophyllum bulbosum* L.	Herb	1	1	1	1
Apiaceae	*Chaerophyllum tenullum* L.	Herb	1	0	0	0
Apiaceae	*Eryngium campestre* L.	Herb	0	0	1	1
Apiaceae	*Laser trilobum* (L.) Borkh.	Herb	1	1	0	0
Apiaceae	*Peucedanum ruthenicum* M. Bieb.	Herb	0	1	0	0
Apiaceae	*Sanicula europaea* L.	Herb	1	0	0	0
Apiaceae	*Smyrnium perfoliatum* L.	Herb	1	0	0	0
Apocynaceae	*Vinca herbacea* Waldst. & Kit.	Herb	1	0	1	1
Aquifoliaceae	*Cotinus coggygria* Scop.	Shrub	1	1	1	0
Araliaceae	*Hedera pastuchowii* Woronow	Vine	1	0	0	0
Aristolochiaceae	*Aristolochia iberica* Fisch. & C. A. Mey. ex Boiss.	Herb	1	0	0	0
Asparagaceae	*Asparagus verticillatus* L.	Herb	1	1	1	0
Aspleniaceae	*Asplenium adiantum-nigrum* L.	Fern	1	0	0	0
Aspleniaceae	*Asplenium trichomanes* L.	Fern	1	1	0	0
Aspleniaceae	*Ceterach officinarum* Willd.	Fern	1	1	0	0
Asteraceae	*Achillea millefolium* L.	Herb	0	0	1	1
Asteraceae	*Cichorium intybus* L.	Herb	1	1	1	1
Asteraceae	*Crepis marschallii* (C. A. Mey.) F. Schultz	Herb	1	1	0	0
Asteraceae	*Hieracium pilosella* L.	Herb	0	0	1	1
Asteraceae	*Hieracium vulgatum* Fries	Herb	0	0	1	1
Asteraceae	*Lapsana communis* L.	Herb	1	0	0	0

Asteraceae	*Pyrethrum corymbosum* (L.) Willd.	Herb	1	0	1	1
Asteraceae	*Senecio vernalis* Waldst. & Kit.	Herb	0	0	1	1
Asteraceae	*Solidago virgaurea* L.	Herb	1	1	1	0
Asteraceae	*Taraxacum officinale* Wigg.	Herb	1	1	1	1
Asteraceae	*Tragopogon graminifolium* DC.	Herb	1	0	0	0
Asteraceae	*Xeranthemum squarosum* Boiss.	Herb	1	0	1	1
Berberidaceae	*Berberis vulgaris* L.	Shrub	1	1	1	0
Boraginaceae	*Aegonychon purpureo-caeruleum* (L.) Holub.	Herb	0	0	1	1
Boraginaceae	*Anchusa italica* Retz.	Herb	1	0	0	0
Boraginaceae	*Anchusa leptophylla* Roem. & Schult.	Herb	0	0	1	1
Boraginaceae	*Brunnera macrophylla* (Adams) Johnst.	Herb	1	0	0	0
Boraginaceae	*Buglossoides arvensis* (L.) Johnst.	Herb	0	0	1	1
Boraginaceae	*Echium rubrum* Jacq.	Herb	0	0	1	1
Boraginaceae	*Echium vulgare* L.	Herb	0	0	1	1
Boraginaceae	*Lappula barbata* (M. Bieb.) Guerke	Herb	1	1	1	1
Boraginaceae	*Myosotis arvensis* (L.) Hill	Herb	0	1	1	1
Boraginaceae	*Myosotis sparsiflora* Pohl	Herb	1	1	1	1
Boraginaceae	*Onosma tenuiflora* Willd.	Herb	0	0	1	1
Brassicaceae	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	Herb	1	1	1	1
Brassicaceae	*Allysum alyssoides* (L.) L.	Herb	0	0	1	1
Brassicaceae	*Allysum tortuosum* Waldst. & Kit. ex Willd.	Herb	0	0	0	1
Brassicaceae	*Bryonia dioica* Jacq.	Herb	0	0	1	0
Brassicaceae	*Capsella bursa-pastoris* (L.) Medik.	Herb	1	0	0	0
Brassicaceae	*Erysimum aureum* M. Bieb. ■	Herb	1	1	1	1
Brassicaceae	*Hesperis matronalis* L.	Herb	1	1	1	0
Brassicaceae	*Isatis iberica* Steven ■	Herb	0	0	1	1
Campanulaceae	*Campanula kachetica* Kantsch. ●	Herb	0	0	0	1
Campanulaceae	*Campanula oblongifolia* (K. Koch) Charadze	Herb	1	1	1	0
Campanulaceae	*Campanula rapunculoides* L.	Herb	1	1	1	0
Caprifoliaceae	*Lonicera caprifolium* L.	Shrub	1	1	1	0
Caprifoliaceae	*Lonicera caucasica* Pall.	Shrub	1	1	1	0
Caprifoliaceae	*Lonicera iberica* M. Bieb.	Shrub	1	1	1	0
Caryophylaceae	*Dianthus orientalis* Adams	Herb	0	0	1	1
Caryophylaceae	*Gypsophila elegans* M. Bieb.	Herb	0	0	1	1
Caryophylaceae	*Melandrium latifolium* (Poir.) Maire	Herb	0	0	1	1
Caryophylaceae	*Minuartia micrantha* Schischk.	Herb	1	0	1	1
Caryophylaceae	*Silene spergulifolia* (Willd.) M. Bieb.	Herb	0	1	1	1
Caryophylaceae	*Stellaria holostea* L.	Herb	1	1	1	1
Celastraceae	*Euonymus europaea* L.	Sec. Tree	1	1	0	0
Celtidaceae	*Celtis caucasica* Willd. ▲	Tree	1	1	1	0
Cistaceae	*Helianthemum nummularium* (L.) Mill.	Herb	0	0	1	1
Cistaceae	*Helianthemum salicifolium* (L.) Mill.	Herb	0	0	1	1

Colchicaceae	*Colchicum szovitzii* Fritsch. ex Mey.	Geophytes	0	0	1	1
Colchicaceae	*Merendera trigina* (Steven ex Adams) Stapf	Geophytes	0	0	1	1
Convallariaceae	*Convallaria transcaucasica* Utkin ex Grossh.	Geophytes	1	1	0	0
Convallariaceae	*Polygonatum glaberrimum* K. Koch	Geophytes	1	1	0	0
Convolvulaceae	*Calystegia silvatica* (Kit.) Griseb.	Herb	1	1	1	0
Convolvulaceae	*Convolvulus arvensis* L.	Herb	1	1	1	1
Cornaceae	*Cornus mas* L.	Sec. Tree	1	1	0	0
Cornaceae	*Swida australis* (C.A. Mey.) Pojark.	Shrub	1	1	1	0
Corylaceae	*Carpinus caucasica* Grossh.	Tree	1	1	0	0
Corylaceae	*Carpinus orientalis* Mill.	Tree	1	1	1	0
Corylaceae	*Corylus avellana* L.	Sec. Tree	1	1	1	0
Crassulaceae	*Sedum caucasicum* (Grossh.) Boriss.	Herb	1	0	1	1
Cupressaceae	*Juniperus oblonga* M. Bieb.	Shrub	0	1	1	0
Cupressaceae	*Platycladus orientalis* (L.) Franko	Shrub	0	0	1	0
Cyperaceae	*Carex cuspidata* Host	Sedge	1	0	0	0
Cyperaceae	*Carex sylvatica* Huds.	Sedge	1	1	0	0
Dioscoreaceae	*Tamus communis* L.	Vine	1	0	0	0
Dipsacaceae	*Cephalaria media* Litv.	Herb	1	1	1	1
Dipsacaceae	*Dipsacus lacinatus* L.	Herb	1	1	1	1
Dipsacaceae	*Scabiosa columbaria* L.	Herb	0	1	1	1
Euphorbiaceae	*Euphorbia helioscopia* L.	Herb	1	1	1	1
Euphorbiaceae	*Euphorbia squamosa* Willd.	Herb	0	0	1	1
Euphorbiaceae	*Euphorbia stricta* L.	Herb	1	1	1	0
Fabaceae	*Anthyllis lachnophora* Juz. ■	Herb	0	0	1	1
Fabaceae	*Astragalus brachycarpus* M. Bieb.	Herb	0	0	1	1
Fabaceae	*Lathyrus laxiflorus* Desf.) O. Kuntze	Herb	1	0	0	0
Fabaceae	*Lathyrus nissoila* L.	Herb	0	0	1	1
Fabaceae	*Lathyrus sphaericus* Retz.	Herb	1	0	0	0
Fabaceae	*Lens ervoides (*Brign.) Grande	Herb	0	0	0	1
Fabaceae	*Lotus caucasicus* Kuprian. ex Juz. ■	Herb	0	0	1	1
Fabaceae	*Medicago arabica* (L.) Huds.	Herb	1	0	1	1
Fabaceae	*Medicago coerulea* Less. ex Lebed.	Herb	0	0	0	0
Fabaceae	*Melilotus officinalis* (L.) Pall.	Herb	1	1	1	1
Fabaceae	*Onobrychis cyri* Grossh. ■	Herb	0	0	1	1
Fabaceae	*Orobus aureus* Stev.	Herb	1	0	0	0
Fabaceae	*Pisum elatius* M. Bieb.	Herb	1	0	0	0
Fabaceae	*Robinia pseudoacacia* L.	Tree	1	1	1	0
Fabaceae	*Trifolium arvense* L.	Herb	0	0	1	1
Fabaceae	*Trifolium campestre* Schreb.	Herb	0	0	1	1
Fabaceae	*Trifolium scabrum* L.	Herb	0	0	1	1
Fabaceae	*Trifolium tumens* Steven ex M. Bieb.	Herb	1	0	1	1
Fabaceae	*Vicia grandiflora* Scop.	Herb	1	1	1	1

Fabaceae	*Vicia johannis* Tamamsch.	Herb	1	0	0	0
Fabaceae	*Vicia lutea* L.	Herb	1	0	1	1
Fabaceae	*Vicia sativa* L.	Herb	0	1	1	1
Fabaceae	*Vicia trunculata* Fisch. ex M. Bieb.	Herb	1	1	1	1
Fagaceae	*Fagus orientalis* Lipsky	Tree	1	0	0	0
Fagaceae	*Quercus iberica* Steven	Tree	1	1	0	0
Fumaraceae	*Corydalis marschalliana* (Pall. ex Willd.) Pers.	Herb	1	1	1	0
Geraniaceae	*Erodium cicutarium* (L.) L'Her.	Herb	1	1	1	1
Geraniaceae	*Geranium columbinum* L.	Herb	1	1	1	0
Geraniaceae	*Geranium lucidum* L.	Herb	1	1	1	1
Geraniaceae	*Geranium molle* L.	Herb	1	1	1	1
Geraniaceae	*Geranium robertianum* L.	Herb	1	1	0	0
Geraniaceae	*Geranium rotundifolium* L.	Herb	1	0	0	0
Helleboraceae	*Nigella arvensis* L.	Herb	1	0	1	1
Hyacinthaceae	*Muscari szovitsianum* Baker	Geophytes	0	0	1	1
Hyacinthaceae	*Muscari tenuiflorum* Tausch	Geophytes	0	0	1	1
Hyacinthaceae	*Scilla sibirica* Huw.	Geophytes	1	1	0	0
Hypericaceae	*Hypericum perforatum* L.	Herb	1	1	1	1
Iridaceae	*Crocus adamii* J. Gay	Geophytes	0	0	1	1
Lamiaceae	*Acinos arvensis* (Lam.) Dandy	Herb	1	0	0	0
Lamiaceae	*Ajuga genevensis* L.	Herb	1	1	0	0
Lamiaceae	*Ajuga orientalis* L.	Herb	1	1	1	1
Lamiaceae	*Ajuga reptans* L.	Herb	1	0	0	0
Lamiaceae	*Lamium album* L.	Herb	1	1	1	1
Lamiaceae	*Nepeta mussinii* Spreng.	Herb	1	1	1	0
Lamiaceae	*Origanum vulgare* L.	Herb	0	0	1	1
Lamiaceae	*Satureja spicigera* (K. Koch) Boiss.	Herb	0	0	1	0
Lamiaceae	*Stachys atherocalyx* K. Koch	Herb	1	1	1	1
Lamiaceae	*Stachys sylvatica* L.	Herb	1	1	1	0
Lamiaceae	*Thymus karjaginii* Grossh. ■	Herb	1	0	1	1
Liliaceae	*Gagea chanae* Grossh.	Geophytes	0	0	1	1
Linaceae	*Linum austriacum* L.	Herb	0	0	1	1
Malvaceae	*Alcea rugosa* Alef.	Herb	0	0	1	1
Moraceae	*Ficus carica* L.	Tree	1	0	1	0
Moraceae	*Morus alba* L.	Tree	1	1	1	0
Oleaceae	*Fraxinus excelsior* L.	Tree	1	1	0	0
Oleaceae	*Jasminum fruticans* L.	Shrub	1	1	1	0
Oleaceae	*Ligustrum vulgare* L.	Herb	1	1	1	0
Orchidaceae	*Anacamptis pyramidalis* (L.) Rich.	Geophytes	1	1	1	0
Orchidaceae	*Cephalanthera damasonium* (Mill.) Druce	Geophytes	1	1	0	0
Orchidaceae	*Cephalanthera longifolia* (L.) Fritsch	Geophytes	1	1	0	0
Orchidaceae	*Cephalanthera rubra* (L.) Rich.	Geophytes	1	1	0	0

Orchidaceae	*Epipactis helleborine* subsp. *bithynica* (Robatsch) Kreutz	Geophytes	1	1	0	0
Orchidaceae	*Epipactis persica* (Soó) Nannfeldt subsp. *persica*	Geophytes	1	0	0	0
Orchidaceae	*Epipactis purpurata* subsp. *kuenkeleana* (Akhalk., H.Baumann, R.Lorenz & Mosul.) Kreutz	Geophytes	1	0	0	0
Orchidaceae	*Limodorum abortivum* (L.) Sw.	Geophytes	1	0	0	0
Orchidaceae	*Neottia nidus-avis* (L.) Rich.	Geophytes	1	1	0	0
Orchidaceae	*Ophrys oestrifera* M. Bieb. subsp. *oestrifera*	Geophytes	1	1	1	0
Orchidaceae	*Ophrys sphegodes* Mill. subsp. *caucasica* (Woronow ex Grossh.) Soó	Geophytes	1	1	1	0
Orchidaceae	*Orchis morio* subsp. *caucasica* (K.Koch) E.G.Camus, Bergon & A. Camus	Geophytes	0	0	1	0
Orchidaceae	*Orchis purpurea* subsp. *caucasica* (Regel) B. Baumann, H. Baumann, R. Lorenz & R. Peter	Geophytes	1	1	1	0
Orchidaceae	*Orchis simia* Lam.	Geophytes	1	1	1	0
Orchidaceae	*Platanthera chlorantha* (Custer) Rchb.	Geophytes	1	1	0	0
Orobanchaceae	*Orobanche ramosa* L.	Parasite	0	1	1	1
Oxalidaceae	*Oxalis acetosella* L.	Herb	0	1	1	1
Papaveraceae	*Papaver macrostomum* Boiss. & Huet	Herb	1	0	1	1
Papaveraceae	*Papaver rhoeas* L.	Herb	1	0	0	0
Plantaginaceae	*Plantago lanceolata* L.	Herb	1	1	1	1
Poaceae	*Aegilops cylindrica* Host.	Grass	0	0	1	1
Poaceae	*Aegilops tauschii* Coss.	Grass	0	0	1	1
Poaceae	*Aegilops triuncialis* L.	Grass	0	0	1	1
Poaceae	*Aira elegantissima* Schur	Grass	1	0	0	0
Poaceae	*Alopecurus pratensis* L.	Grass	1	0	0	0
Poaceae	*Avena fatua* L.	Grass	0	0	1	1
Poaceae	*Avena sterilis* L.	Grass	0	0	1	1
Poaceae	*Brachypodium pinnatum (*L.) P. Beauv.	Grass	1	1	1	1
Poaceae	*Brachypodium sylvaticum* (Huds.) P. Beauv.	Grass	1	1	0	0
Poaceae	*Briza elatior* Sibth. & Smith	Grass	0	0	1	1
Poaceae	*Bromus japonicus* Thumb.	Grass	0	0	1	1
Poaceae	*Bromus sterilis* L.	Grass	1	0	0	0
Poaceae	*Cynosurus echinatus* L.	Grass	0	0	1	1
Poaceae	*Dactylis glomerata* L.	Grass	1	1	1	1
Poaceae	*Hordeum bulbosum* L.	Geophytes	0	0	1	1
Poaceae	*Hordeum gussoneanum* Parl.	Grass	0	0	1	1
Poaceae	*Hordeum leporinum* Link	Grass	0	1	1	1
Poaceae	*Lolium rigidum* Gaudin	Grass	1	1	1	1
Poaceae	*Melica taurica* K. Koch	Grass	0	0	0	1
Poaceae	*Melica transsilvanica* Schur	Grass	0	0	1	1
Poaceae	*Milium vernale* M. Bieb.	Grass	1	1	1	0
Poaceae	*Phleum phleoides* (L.) Karst.	Grass	1	1	1	1
Poaceae	*Phleum pratense* L.	Grass	0	0	1	1
Poaceae	*Poa bulbosa* L.	Geophytes	1	0	1	1

Poaceae	*Poa bulbosa* L. var. *vivipara* Koel.	Geophytes	1	1	1	1
Poaceae	*Poa nemoralis* L.	Grass	1	1	1	1
Poaceae	*Stipa pulcherimma* K. Koch	Grass	0	0	1	1
Poaceae	*Stipa tirsa* Steven	Grass	0	0	1	1
Polygalaceae	*Polygala transcaucasica* Tamamsch.	Herb	1	1	1	1
Polygonaceae	*Rumex crispus* L.	Herb	1	1	1	0
Primulaceae	*Anagallis arvensis* L.	Herb	0	0	1	1
Primulaceae	*Anagallis foemina* Mill.	Herb	1	0	0	0
Primulaceae	*Cyclamen coum* subsp. *caucasicum* (K. Koch) O. Schwarz p. p.	Geophytes	1	1	0	0
Primulaceae	*Primula macrocalyx* Bunge	Herb	0	1	1	0
Primulaceae	*Primula woronowii* Losinsk. ■	Herb	1	1	1	0
Punicaceae	*Punica granatum* L.	Sec. Tree	0	1	1	0
Ranunculaceae	*Ranunculus bulbosus* L.	herb	0	1	1	0
Ranunculaceae	*Ranunculus grandiflorus* L.	herb	1	1	1	0
Ranunculaceae	*Ranunculus polyanthemus* L.	herb	1	0	0	0
Rhamnaceae	*Paliurus spina christi* Mill.	Shrub	0	0	1	0
Rhamnaceae	*Rhamnus cathartica* L.	Shrub	1	1	1	0
Rhamnaceae	*Rhamnus palasii* Fisch. & C.A. Mey.	Shrub	0	0	1	0
Rosaceae	*Amygdalus incana* Pall.	Shrub	0	1	1	0
Rosaceae	*Cotoneaster integerrimus* Medik.	Shrub	0	1	1	0
Rosaceae	*Cotoneaster morulus* Pojark.	Shrub	1	1	1	0
Rosaceae	*Crataegus pentagina* Waldst. & Kit.	Sec. Tree	1	1	1	0
Rosaceae	*Cruciata laevipes* Opiz	Herb	1	1	1	1
Rosaceae	*Cydonia oblonga* Mill.	Tree	1	1	1	0
Rosaceae	*Filipendula vulgaris* Moench	Herb	0	0	1	1
Rosaceae	*Fragaria vesca* L.	Herb	1	1	1	1
Rosaceae	*Galium coronatum* Sibth. & Smith	Herb	0	0	0	1
Rosaceae	*Galium praemontanum* T. Mardalejshvili ●	Herb	1	0	0	1
Rosaceae	*Galium vaillantii* DC.	Herb	1	1	1	1
Rosaceae	*Galium verticillatum* Danth.	Herb	0	0	0	1
Rosaceae	*Galium verum* L.	Herb	0	0	1	1
Rosaceae	*Geum urbanum* L.	Herb	1	1	1	0
Rosaceae	*Malus orientalis* Uglitzk.	Tree	1	1	1	0
Rosaceae	*Mespilus germanica* L.	Tree	1	1	1	0
Rosaceae	*Potentilla erecta* (L.) Raeusch.	Herb	1	0	1	1
Rosaceae	*Potentilla recta* L.	Herb	0	0	1	1
Rosaceae	*Prunus avium* L.	Tree	1	1	1	0
Rosaceae	*Prunus divaricata* Ledeb.	Sec. Tree	1	1	1	0
Rosaceae	*Prunus mahaleb* L.	Sec. Tree	1	1	1	0
Rosaceae	*Prunus microcarpa* C. A. Mey. ▲	Sec. Tree	1	1	1	0
Rosaceae	*Prunus spinosa* L.	Shrub	0	0	1	0
Rosaceae	*Pyracantha coccinea* M. Roen.	Shrub	1	1	1	0

Rosaceae	*Pyrus caucasica* Fed. ■	Tree	1	1	1	0
Rosaceae	*Rosa canina* L.	Shrub	1	1	1	0
Rosaceae	*Rubus anatolicus* (Focke) Focke ex Hausskn.	Shrub	1	1	1	0
Rosaceae	*Sanguisorba officinalis* L.	Herb	1	0	0	0
Rosaceae	*Spiraea hypericifolia* L.	Shrub	1	1	1	0
Rubiaceae	*Asperula odorata* L.	Herb	1	0	0	0
Rutaceae	*Dictamnus caucasicus* (Fisch. & C. A. Mey.) Grossh.	herb	1	0	0	0
Salicaceae	*Populus tremula* L.	Tree	1	1	0	0
Sambucaceae	*Sambucus ebulus* L.	Herb	1	1	1	0
Sambucaceae	*Sambucus nigra* L.	Shrub	1	0	0	0
Scrophulariaceae	*Linaria genistifolia* (L.) Mill.	Herb	0	0	1	1
Scrophulariaceae	*Scrophularia grossheimii* Schischk.	Herb	1	1	1	1
Scrophulariaceae	*Verbascum pyramidatum* M. Bieb.	Herb	1	0	1	1
Scrophulariaceae	*Verbascum saccatum* K. Koch	Herb	0	0	1	1
Scrophulariaceae	*Veronica officinalis* L.	Herb	0	1	1	0
Scrophulariaceae	*Veronica serphylligolia* L.	Herb	1	0	0	0
Scrophulariaceae	*Veronica urticifolia* Jacq.	Herb	1	0	0	0
Simaroubaceae	*Ailanthus altissima* (Mill.) Swingle	Tree	0	1	1	0
Solanaceae	*Solanum nigrum* L.	Herb	1	0	0	0
Tiliaceae	*Tilia begoniifolia* Steven	Tree	1	1	0	0
Ulmaceae	*Ulmus minor* Mill. ▲	Tree	1	1	1	0
Urticaceae	*Parietaria judaica* L.	Herb	0	0	0	1
Urticaceae	*Parietaria officinalis* L.	Herb	0	0	0	1
Urticaceae	*Urtica dioica* L.	Herb	0	1	1	1
Valerianaceae	*Valeriana officinalis* L.	Herb	1	1	1	0
Viburnaceae	*Viburnum lantana* L.	Shrub	1	1	0	0
Violaceae	*Viola nemausensis* Jord.	Herb	0	1	1	1
Violaceae	*Viola odorata* L.	Herb	1	1	1	1
Violaceae	*Viola reichenbachiana* Jord. ex Boreau	Herb	1	1	1	1
Violaceae	*Viola suavis* M. Bieb.	Herb	1	1	1	1
Viscaceae	*Viscum album* L.	Parasite	1	1	0	0