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FLORISTIC SURVEY OF SUMMER ASPECT IN CHOSEN CHINA CLAY PITS IN WESTERN BOHEMIA

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Abstract

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Five different china clay pits in the western part of the Czech Republic were explored and plant species were determined. These chosen pits were: Hájek-western part, Chlumčany, Horní Bříza, Otovice and Podlesí II. China clay pits with active excavation represent a specific environment concerning both physical and chemical characteristics. This article is presenting a list of the higher plants which were found within active excavation or former excavation areas. Species with a protection status according to the Czech legislation are presented in more detail. 189 different species have been found in total, including 2 species from category C4 – potentially vulnerable taxa, 6 species from category C3 – endangered taxa and 1 species from the C1 – critically threatened taxa from the Red List of Vascular Plants of the Czech Republic. 28 different species occurred at each of the five sites. Predominant species favour sandy substratum and bare surface.

Keywords: china clay pit, kaolin, species list, natural restoration, vegetation

INTRODUCTION

China clay pits represent a specific environment for plants by both its chemical and physical parameters. China clay is a substrate of light gray to white colour, mostly with neutral or acidic pH reaction. Its composition shows a high amount of loam particles, mostly kaolinite, which comes from the weathering of base rocks full of minerals, with a high amount of feldspar. It always contains quartz. All kaolinite deposits in the Czech Republic originate from the weathering of feldspar rock. Kaolinite is the dominating mineral within all loam minerals in the Czech Republic (Starý, 2009). In 2012 there were 70 deposits registered, but only 15 of them were exploited (Starý, 2013). The Czech Republic is a prominent producer of china clay with high quality, which is mainly used for ceramic and paper purposes. The china clay is exploited by surface mining in storey pits, nevertheless, also underground mines were open in the past (Nevřeň in Plzeň district, Hosín close to České Budějovice). Because of the technology of china clay progressive exploitation, working districts are opened for many decades. This fact leads to the natural succession of vegetation in the abandoned sections of the quarries, which can be used for the follow-up restoration of the sites.

In china clay pits there are plant species mainly characteristic of habitats with a low amount of nutrients and sand substrates. We can find aquatic plants here as well because there is often a small lake in the bottom of the pit.

The topic of revitalization of china clay pits and their natural succession was intensively studied in Great Britain in the 1970s and 1980s. Abiotic conditions, mostly the importance of nutrition for natural succession, were studied in Cornwall as early as in 1975 (Bradshaw, 1975). This topic was also investigated by Bradshaw and Chadwick (1980) and Marrs and Bradshaw (1980), who focused on

physical and chemical attributes of different pit substrates. China clay was characterised as very unfavourable substrate for the plant growth for its structure and nutrient availability. Regeneration of abandoned pits, successional series and the impact of organic compounds on regeneration was studied by Roberts *et al.* (1981). Marrs and Bradshaw (1993) recapitulated the principles of primary succession in quarries and china clay pits were chosen as a model system. Recently, the species garniture on china clay substrate was studied in Brasil (De Araújo *et al.*, 2006; Martins *et al.*, 2008) and in China (Zhang and Chu, 2013). The last mentioned study explored the soil seed bank and the vegetation of three china clay quarries near Hong Kong.

Only very scarce results about the vegetation of china clay pits and the impact of china clay mining on the surrounding landscape have been published in the Czech Republic. We could only use the results of the project VaV SP/2d1/141/07 Recultivation and management of non-natural biotops in the Czech Republic (Gremlica *et al.*, 2009). Different attributes of different types of habitats including china clay pits and the specifics of their regeneration were described by Řehounek *et al.* (2010). We need to learn about the natural succession in this type of habitat if we want to use its principles to restore ecological functions of sites.

According to Řehounek *et al.* (2010), these protected species can potentially occur naturally on china clay substrates: C1 – *Ceratophyllum submersum*; C2 – *Utricularia minor*, *Epipactis palustris*, *Diphasiastrum complanatum*, *Potamogeton gramineus*, *Potamogeton alpinus*, *Drosera rotundifolia*, *Lysimachia thyrsiflora*, *Sparganium minimum*; C3 – *Arnica montana*, *Dactylorhiza majalis*, *Potamogeton acutifolius*, *Potamogeton obtusifolius*, *Plathantera bifolia*; C4a – *Isolepis setacea*, *Filago minima*, *Filago arvensis*, *Utricularia australis*, *Spergula morisonii*, *Batrachium circinatum*, *Comarum palustre*, *Vulpia myuros*, *Lycopodium clavatum*, *Veronica scutellata*, *Schoenoplectus lacustris*, *Hypericum humifusum*, *Centaurium erythraea*. There were *Androsace septentrionalis* (C1), *Epipactis palustris* and *Schoenoplectus tabernaemontani* (C2) physically found in Únanov in the Znojmo district, and *Platanthera bifolia, Lycopodium clavatum* and *Potamogeton obtusifolius* found in the Zelená pit near the town of Františkovy Lázně (Melichar and Gremlica (eds.), 2010).

The aim of this study was to survey the vegetation in mostly active china clay pits in the Czech Republic and to define the typical summer aspect of this habitat.

MATERIALS AND METHODS

Five china clay pits with extensive mining or those recently abandoned were chosen for the floristic survey – three quarries in the Karlovy Vary district and two in the Plzeň district in the western part of the Czech Republic. The quarries were chosen on the basis of their size and shape. Another selection factor was the presence of an abandoned section. Phytogeographically they belong to Bohemian-Moravian mesophyticum in the altitudinal range of 380–480 m. a. s. l. The floristic surveys in all the quarries took place in June 2013.

The Description of Chosen Quarries

Hájek-západ

N 50° 17' 40", E 12° 53' 1", 450–480 m. a. s. l., area 0.07 km^2

The Hájek-západ site is located 7 km from the town Karlovy Vary. Its potential vegetation is *Melampyro nemorosi-Carpinetum* and *Luzulo albidae-Quercetum petraeae* (Neuhäuslová, 1997). Its climate belongs to the moderately warm climatic region and to districts MT4 and MT7 (Quitt, 1971). According to the biogeographical segmentation, it belongs to the province of deciduous forests of middle Europe and region 24b Sokolovská pánev (Culek, 1996). At the present time the exploitation has been terminated and restoration is taking place. The floristic survey was performed at the part which is not technically restored yet and it is predestined to be filled by waste substrate from another pit. Mainly slopes with developed vegetation were explored.

Podlesí II

N 50° 16' 26", E 12° 52' 37", 420–445 m. a. s. l., area 0.05 km^2

The Podlesí II site is located to the north of Karlovy Vary, about 5 km from the town. Its potential vegetation is *Luzulo albidae-Quercetum petraeae* (Neuhäuslová, 1997). Its climate belongs to the moderately warm climatic region and to districts MT4 and MT7 (Quitt 1971). According to the biogeographical segmentation it belongs to the province of deciduous forests of middle Europe and region 24b Sokolovská pánev (Culek, 1996). At the present time exploitation still takes place so mainly a young succesional stage was detected.

Otovice

N 50° 15' 51", E 12° 51' 19", 384–433 m. a. s. l., current area 0.18 km^2

The Otovice site is located 4 km to the north of the centre of Karlovy Vary in the northern part of Otovice cadastre. Its potential vegetation is *Luzulo albidae-Quercetum petraeae* (Neuhäuslová, 1997). Its climate belongs to the moderately warm climatic region and to districts MT4 and MT7 (Quitt, 1971). According to the biogeographical segmentation it belongs to the province of deciduous forests of middle Europe and region 24b Sokolovská pánev (Culek, 1996). At the present time exploitation still takes place.

Horní Bříza

N 49° 52' 4", E 13° 21' 15", 445–480 m. a. s. l., current area 0.68 km^2

The Horní Bříza site is located in the forests 14 km north of the centre of Plzeň. It is the second

biggest china clay pit in the Czech Republic. Its potential vegetation is *Vaccinio vitis-idaeae-Quercetum* (Neuhäuslová, 1997). Its climate belongs to the moderately warm climatic region and to district MT11 (Quitt, 1971). According to the biogeographical segmentation it belongs to the province of deciduous forests of middle Europe and region 31a Plzeňská pahorkatina vlastní (Culek, 1996). At the present time exploitation still takes place. From this pit we chose only some representative parts for the survey because of its large area and intensity of exploitation.

Chlumčany

N 49° 37' 8", E 13° 16' 26", 350–406 m. a. s. l., current area 0.45 km^2

The Chlumčany site is located in the Plzeň-South district in the cadastres of Chlumčany, Dnešice, Dobřany and Vstiš. Its potential vegetation is *Luzulo albidae-Quercetum petraeae* (Neuhäuslová, 1997). Its climate belongs to the moderately warm climatic region and to district MT11 (Quitt, 1971). According to the biogeographical segmentation it belongs to the province of deciduous forests of middle Europe and region 31a Plzeňská pahorkatina vlastní (Culek, 1996). China clay from this pit is used for paper and ceramic industry. At the present time exploitation still takes place in some parts.

In this paper only the species found directly in the pit part are presented; the species found in the vicinity of the quarries are not included. The complete data from all the sites studied are presented in Tab. I, Results, as well as comments on the all endangered species found.

RESULTS

We found 186 species in total in all the five sites, which is about 5% of all species stated in Czech flora (Danihelka *et al.*, 2012). From this amount, 28 species occur in all and 15 species in four the sites studied so we state they are species typical of china clay quarries in the region of Western Bohemia. The individual quarries differ significantly in the total number of species found. The highest number of species was found at Chlumčany (113 species), then Otovice (96 species), Horní Bříza (78 species), Podlesí (76 species) and the lowest number was found at Hájek (66 species).

According to the Red List (Grulich, 2012), six species belong to the endangered species category and one to critically endangered species category. These are: *Hypericum humifusum, Filago arvensis, Filago minima, Leersia oryzoides, Lycopodium clavatum, Pyrola chlorantha* and *Vulpia myuros.*

Typical Species of China Clay Pits

Group of typical species is composed of 8 woody plant species, both pioneers *Salix* sp., *Betula pendula*, *Populus tremula* or *Pinus sylvestris* and other tree species

1: *China clay open pit Chlumčany – its abandoned bottom and still mined slope*
author: Botková, 2013

I: *The occurrence of plant species in china clay pits in Plzeň and Karlovy Vary Area (Otovice, Podlesí II, Hájek – western part, Horní Bříza and Chlumčany)*

	Otovice	Podlesí	Hájek	H. Bříza	Chlumčany
Present at all 5 sites					
Artemisia vulgaris	+	+	+	+	+
Betula pendula	+	+	+	+	+
Calamagrostis epigejos	+	+	+	+	+
Cerastium arvense	+	+	+	+	+
Cirsium arvense	+	+	+	+	+
Daucus carota	+	+	+	+	+
Epilobium angustifolium	+	+	+	+	+
Festuca rubra	+	+	+	+	+
Hieracium bauhinii	+	+	+	+	+
Holcus lanatus	+	+	+	+	+
Hypericum perforatum	+	+	+	+	+
Juncus effusus	+	+	+	+	+
Lotus corniculatus	+	+	+	+	+
Medicago lupulina	+	+	+	+	+
Phleum phleoides	+	+	+	+	+
Picea abies	+	+	+	+	+
Pinus sylvestris	+	+	+	+	+
Plantago major	+	+	+	+	+
Poa annua	+	+	+	+	+
Poa compressa	+	+	+	+	+
Poa trivialis	+	+	+	+	+
Populus tremula	+	+	+	+	+
Rumex crispus	+	+	+	+	+
Salix caprea	+	+	+	+	+
Taraxacum sect. *Ruderalia*	+	+	+	+	+
Trifolium hybridum	+	+	+	+	+
Trifolium repens	+	+	+	+	+
Tussilago farfara	+	+	+	+	+
Present at 4 sites					
Achillea millefolium agg.	.	+	+	+	+
Deschampsia cespitosa	+	+	+	.	+
Erigeron annuus	+	+	.	+	+
Hieracium pilosella	+	+	+	.	+
Hieracium sabaudum	+	+	+	.	+
Larix decidua	+	+	+	+	.
Poa pratensis	+	+	.	+	+
Polygonum aviculare	+	+	.	+	+
Prunus avium	+	+	+	.	+
Quercus petraea	+	+	+	.	+
Ranunculus repens	+	+	+	.	+
Rumex acetosella	+	+	.	+	+
Sagina procumbens	+	+	.	+	+
Spergularia rubra	+	+	.	+	+
Trifolium medium	+	.	+	+	+
Tripleurospermum inodorum	+	+	.	+	+

	Otovice	Podlesí	Hájek	H. Bříza	Chlumčany
Present at 3 sites					
Agrostis capillaris	.	+	.	+	+
Carduus acanthoides	+	+	.	+	.
Carex ovalis	+	+	.	+	.
Crataegus sp.	+	+	.	.	+
Equisetum arvense	.	+	+	.	+
Festuca heterophylla	+	.	+	+	.
Lactuca serriola	+	+	.	.	+
Leontodon autumnalis	+	+	.	+	.
Lepidium ruderale	.	+	.	+	+
Lychnis flos-cuculi	+	+	+	.	.
Melilotus albus	+	.	+	.	+
Plantago lanceolata	.	.	+	+	+
Poa angustifolia	.	+	+	.	+
Poa nemoralis	.	+	+	.	+
Potentilla anserina	+	.	.	+	+
Sorbus aucuparia	+	+	.	.	+
Tanacetum vulgare	+	.	+	.	+
Typha latifolia	.	+	+	.	+
Urtica dioica	+	+	.	+	.
Veronica officinalis	+	.	.	+	+
Vicia angustifolia	+	+	.	+	.
Vicia tetrasperma	+	.	.	+	+
Present at 2 sites					
Acer platanoides	.	+	.	.	+
Ajuga reptans	+	+	.	.	.
Alisma plantago-aquatica	.	.	.	+	+
Anthoxanthum odoratum	+	.	+	.	.
Arrhenatherum elatius	.	.	+	+	.
Astragalus glycyphyllos	.	+	+	.	.
Bromus hordeaceus	.	.	+	+	.
Campanula patula	.	+	+	.	.
Carduus crispus	.	+	.	.	+
Carex pilulifera	+	.	.	+	.
Centaurium erythraea	.	.	.	+	+
Cerastium holosteoides	+	.	.	.	+
Cirsium vulgare	+	.	.	.	+
Dactylis glomerata	+	+	.	.	.
Echium vulgare	.	.	.	+	+
Elytrigia repens	+	+	.	.	.
Erigeron acris	.	.	.	+	+
Fagus sylvatica	+	.	+	.	.
Festuca gigantea	.	.	+	.	+
Festuca pratensis	+	.	.	.	+
Festuca pratensis agg.	.	.	+	+	.
Filago arvensis	.	.	.	+	+
Fragaria viridis	.	.	.	+	+
Gnaphalium uliginosum	+	+	.	.	.
Hypericum humifusum	.	+	.	.	+

	Otovice	Podlesí	Hájek	H. Bříza	Chlumčany
Juncus tenuis	.	.	.	+	+
Leucanthemum vulgare	.	+	+	.	.
Lupinus polyphyllus	.	.	+	.	+
Medicago minima	.	.	.	+	+
Potentilla erecta	+	.	.	.	+
Potentilla reptans	.	.	.	+	+
Prunella vulgaris	.	.	.	+	+
Robinia pseudacacia	.	.	.	+	+
Rubus caesius	.	.	.	+	+
Senecio vulgaris	+	.	.	.	+
Stellaria media	+	.	.	.	+
Veronica chamaedrys	+	.	.	.	+
Vulpia myuros	.	.	.	+	+
Presence only at 1 site					
Acer negundo	.	.	.	.	+
Acer pseudoplatanus	.	.	.	.	+
Agrostis stolonifera	+	.	.	.	.
Alchemilla vulgaris agg.	+	.	.	.	.
Anagallis arvensis	.	.	.	.	+
Arenaria serpyllifolia	.	.	+	.	.
Atriplex prostrata	+	.	.	.	.
Avenella flexuosa	+	.	.	.	.
Bromus sp.	+	.	.	.	.
Calluna vulgaris	.	.	.	+	.
Campanula rotundifolia	+	.	.	.	.
Capsella bursa-pastoris	+	.	.	.	.
Carex pallescens	.	.	.	.	+
Cephalanthera damasonium	.	.	.	.	+
Convolvulus arvensis	.	.	.	.	+
Corylus avellana	+	.	.	.	.
Crepis biennis	+	.	.	.	.
Crepis species	.	+	.	.	.
Cruciata laevipes	.	.	+	.	.
Cytisus nigricans	.	.	.	.	+
Cytisus scoparius	.	.	.	.	+
Echinochloa crus-galli	.	.	.	.	+
Equisetum palustre	.	.	.	.	+
Equisetum sylvaticum	+	.	.	.	.
Fallopia convolvulus	.	.	.	.	+
Festuca arundinacea	.	.	+	.	.
Filago minima	.	.	.	+	.
Fragaria species	.	.	.	.	+
Fraxinus excelsior	.	.	+	.	.
Galeopsis pubescens	+	.	.	.	.
Galium aparine	.	.	.	.	+
Galium verum	.	.	+	.	.
Geranium palustre	+	.	.	.	.
Geum urbanum	.	.	.	.	+
Glechoma hederacea	.	.	.	.	+
Heracleum mantegazzianum	+	.	.	.	.

	Otovice	Podlesí	Hájek	H. Bříza	Chlumčany
Hieracium laevigatum	.	.	+	.	.
Chenopodium album	.	.	.	.	+
Chenopodium album agg.	+	.	.	.	.
Juncus bufonius	.	+	.	.	.
Lamium purpureum	.	.	.	.	+
Lathyrus heterophyllus	.	.	+	.	.
Lathyrus pratensis	.	.	.	+	.
Leersia oryzoides	.	.	.	.	+
Linaria vulgaris	.	.	.	+	.
Lolium perenne	.	.	.	+	.
Luzula campestris	.	+	.	.	.
Lycopodium clavatum	.	+	.	.	.
Melampyrum nemorosum	.	.	+	.	.
Microrrhinum minus	.	.	.	.	+
Papaver somniferum	.	.	.	.	+
Persicaria hydropiper	+	.	.	.	.
Petasites hybridus	.	.	.	.	+
Picris hieracioides	.	.	.	+	.
Pinus strobus	+	.	.	.	.
Plantago media	.	.	.	.	+
Poa bulbosa	.	.	.	+	.
Potamogeton natans	.	.	.	+	.
Pyrola chlorantha	.	.	.	+	.
Reseda lutea	.	.	.	.	+
Rorippa palustris	.	+	.	.	.
Rosa sp.	.	.	.	.	+
Rumex acetosa	+	.	.	.	.
Rumex obtusifolius	.	+	.	.	.
Scleranthus annuus	+	.	.	.	.
Scrophularia nodosa	.	.	.	+	.
Securigera varia	.	+	.	.	.
Silene nutans	.	.	+	.	.
Solanum nigrum	.	.	.	.	+
Stellaria graminea	+	.	.	.	.
Stellaria holostea	+	.	.	.	.
Symphytum officinale	+	.	.	.	.
Trifolium alpestre	.	.	.	.	+
Trifolium arvense	.	.	.	.	+
Trifolium incarnatum	+	.	.	.	.
Urtica urens	+	.	.	.	.
Vaccinium myrtillus	.	+	.	.	.
Vaccinium vitis-idaea	.	.	.	.	+
Verbascum densiflorum	.	.	+	.	.
Vicia cracca	.	.	.	+	.
Vicia hirsuta	.	.	.	.	+
Viola arvensis	+	.	.	.	.
Viola riviniana	.	.	.	.	+
Total number of species	**96**	**76**	**66**	**78**	**113**

The species are listed in groups according to their presence in particular quarries. The presence is marked by symbol „+“, absence „ .“ Red List species are in bold.

from surrounding vegetation (*Quercus petraea*, *Larix decidua*), 10 grass species (mainly *Poa* sp.) including invasive *Calamagrostis epigejos*, which occurs on heaps but also in more successionally developed communities, and 26 dicotyledon species. No species from the Red List was found at more than two pits.

Annotation to Species With Protection Status

Filago arvensis

This species was highly abundant at Chlumčany and Horní Bříza. This species is classified as an endangered species (C3) according to the legislation. The habitats typical of this species are sparse forests, road edges, sands, quarries and light pine forests. It likes dry and warm habitats with highly drying soils with small amounts of nutrients. Earlier it was abundant in the entire Czech Republic but because of landscape eutrophisation it became endangered (Slavík and Štěpánková, 2004).

Filago minima

This species is classified as an endangered species (C3) according to the legislation. Its habitat is fairly similar to the habitat of *Filago arvensis*. Earlier it was abundant in the entire Czech Republic as well but because of landscape eutrophisation it became endangered (Slavík and Štěpánková, 2004).

Hypericum humifusum

Only several individuals of this species were found at the sparse vegetation of Chlumčany. It is classified as an endangered species (C3) according to the legislation. The habitat typical of this species is naked bottoms of ponds, banks, sediment loads or ditches and sand pits. It prefers acid substrates (Hejný and Slavík, 2003).

Leersia oryzoides

This species was found at the hygrophilous vegetation of Chlumčany. It is classified as an endangered species (C3) according to the legislation. Its distribution in the Czech Republic is sparse to scarce. The habitat typical of this species is sandy and marshy banks of rivers and ponds with eutrophic water (Kubát *et al*., 2010).

Lycopodium clavatum

This species was found at Podlesí only. In the flora of the Czech Republic it is classified as an endangered species (C3). The habitat typical of this species is acid substrates, often dry pastures or light forests. Its distribution in the Czech Republic is sparse to abundant (Hejný and Slavík, 2003).

Pyrola chlorantha

This species was found at Horní Bříza. In the same habitat we found tree species like *Betula pendula*, *Pinus sylvestris*, *Picea abies* and *Populus tremula*. According to the legislation it is classified as a critically endangered species (C1). Its typical habitats are dry light forests, particularly pine groves. Its distribution in the Czech Republic is rare (Kubát *et al*., 2010).

Vulpia myuros

This species was found in the vegetation of Horní Bříza and Chlumčany. In the flora of the Czech Republic it is classified as an endangered species (C3). Its typical habitats are sands and the edges of pine groves in non-calcareous substrates. Its distribution in the Czech Republic is sparse (Kubát *et al*., 2010).

DISCUSSION

In five china clay quarries in the Karlovy Vary and Plzeň districts 189 species were found, including some species mentioned in the Red Lists of the Czech Republic (Grulich, 2012). They were two species from category C4 – potentially vulnerable taxa *(Centaurium erythraea, Cephalanthera damasonium),* 6 species from category C3 – endangered taxa (*Filago arvensis, Filago minima, Hypericum humifusum, Leersia oryzoides, Vulpia myuros, Lycopodium clavatum*), and 1 species from category C1 – critically threatened taxa (*Pyrola chlorantha*). These species are most often the species requiring bare substrates, sparse vegetation and sandy substrates or substrates with low amounts of nutrients so their abundance is dependent on the mining progress. Since no species from the Red List was found at more than two pits, we conclude that there is no endangered plant species in summer aspect which would be common in china clay pits.

Comparing our findings to Řehounek *et al*. (2010), three of the Red List species presented here are newly described for this type of habitat. The total number of species in china clay pits corresponds to the findings of Gremlica *et al*. (2009), who refers 114 plant species at Únanov china clay pit and 91 plant species at Buškovice china clay pit. The lowest number of species was found at Hájek, which could be due to the more developed vegetation, thus another successional stage compared to the other sites and due to the on-going reclamation. The highest number of species occurred at Chlumčany which has the most diverse habitat. Dependence of species richness on the quarry area was not significant for our results. We did not find increased abundance of invasive or expansive species in any of the sites, which can be explained by their insignificant occurrence in close surroundings and probably by the specifics of china clay as a substrate.

Wet habitats of china-clay pits were rather poor in number of species comparing to similar habitats in sand pits (Řehounková and Prach, 2008), which is probably the result of different water regime in these substrates. Moreover water pools in china clay pits are usually muddy with clay particles.

CONCLUSION

The species present at the pits were mostly species requiring bare substrates, sparse vegetation and sandy substrates or substrates with low amounts of nutrition. Many of typical species found are species of open sites (e.g. *Betula pendula*, *Salix caprea*), abandoned lands (e.g. *Daucus carota*, *Cirsium arvense*) or often disturbed sites (e.g. *Poa annua*, *Plantago major*). Most of these species produce large amounts of small seeds which can reach large distances.

The species composition corresponds with the early stages of succession although there were also some species of older stages of succession found. Expansive and invasive species were found only in few individuals. Few threatened species were found, which proves that current management enables its occurrence, probably by limitation of species with strong competitive attributes.

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