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Epilithic and aerophilic diatoms in the artificial environment of Kungsträdgården metro station, Stockholm, Sweden

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Abstract: The Kungsträdgården metro station is an artificial and urban subsurface environment illuminated with artificial light. Its ecosystem is almost completely unknown and as a first step to better understand the biology and rock wall habitats the diatom flora was investigated. A total of 12 species were found growing on the rock walls of Kungsträdgården metro station. The results show the diatom flora in Kungsträdgården to be dominated by e.g. *Diademsma contenta*, *Diademsma perpusilla*, *Pinnularia appendiculata*, *Nitzschia amphibia*, *Nitzschia sinuata* and *Diploneis ovalis*. One species, *Caloneis* cf. *aerophila*, has never been reported from Sweden before. Significant differences in the species composition between the sampling sites indicate Kungsträdgården metro station to be a heterogeneous habitat that provides different microhabitats.

Keywords: epilithic diatoms; lampenflora; metro station

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INTRODUCTION

Urban underground facilities like utility tunnels (e.g. drainage, sewers, water, electrical power, gas, central heating) and tunnels for transportation is a crucial part of the urban infrastructure. Some urban subsurface areas, like metro systems, are constructed to daily hold and transport large quantities of people. An increased human presence in such systems urges the need to increase our understanding and knowledge of these environments. From an infrastructural or engineering point of view these environments are well known but other areas of the urban subsurface realm, like its biosphere, are still less known. This opens up a whole new niche for ecological research.

So far, there is a gap in our knowledge about the presence of diatoms in subsurface urban settings. In caves, on the other hand, diatoms have been studied at several locations (e.g. St. Clair and Rushforth, 1976; Garbacki et al., 1999; Lauriol et al., 2006; Pouličková and Hašler, 2007; Mulec et al., 2008), typically in karst caves. Kashima et al. (1987), however, studied diatoms of the genus *Melosira* and their contribution in the production of

coralloid speleothems in a cave developed in deposits of quaternary pyroclastic flows.

Caves are considered to be a difficult environment for autotrophic organisms to inhabit since they need light for the process of photosynthesis. Diatoms seem to be able to grow to a point where light conditions are about 54-127 lx (Abdullin, 2011), but the weak light affects both the morphology and physiology of diatom cells. Cell volume, chloroplast size and number of thylakoids increases with decreasing light intensities. Light quality affects the diatom cells; blue light seems to induce the highest rate of photosynthesis (Jørgensen, 1977). However, artificial light can also be utilized and the term Lampenflora is used collectively for all photosynthetic organisms that live in caves with artificial illumination (Roldán and Hernández-Marín, 2009; Mulec, 2012). Diatoms as Lampenflora have been studied in show caves e.g. in Slovenia (Mulec et al., 2008), the Czech Republic (Pouličková and Hašler, 2007) and in Kentucky, USA (Smith and Olson, 2007) and in catacombs (Albertano, 1993; Albertano and Urzi, 1999; Llop et al., 2012). A characteristic of Lampenflora is that its species diversity is low compared to that of other habitats, e.g. cave entrances (Mulec, 2012).

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Here we report a study of diatoms, conducted in Kungsträdgården metro station, which is an environment illuminated with artificial light. It is the first study of diatoms in this type of urban environment. The aim of the study was to describe the aerophytic diatom community of Kungsträdgården metro station and increase the understanding of the wall habitats as well as how the diatoms dispersed into this system.

Epilithic and aerophilic diatoms

Diatoms are single-celled algae, which can be found in almost every aquatic habitat, often in high abundances and species richness (Julius and Theriot, 2010). Due to the presence of silica in their cell walls (the frustules), diatom morphology remains preserved during sedimentation and they are known from fossil assemblages from the Jurassic and onwards (Round et al., 1990). Their high abundances and often high species richness together with the fact that the species composition is very sensitive to factors in the environment, such as pH, salinity, nutrient availability and temperature, make the diatoms excellent as paleoenvironmental indicators (Smol and Stoermer, 2010). Diatoms are also used for monitoring water quality and classifications thereof (Stevenson et al., 2010).

Diatoms are divided into planktonic taxa and benthic taxa, based on the ecological region in which they can be found. The ecology of benthic diatoms is less understood than that of planktonic diatoms (Round et al., 1990). Benthic diatom communities can be categorized by their preferred substrates, e.g. epipsammon (growing on sand grains), epiphyton (growing on submerged macrophytes or large microalgae), epizoon (growing on animals) or epilithon (growing on hard substrata, e.g. on rock) (Pouličková et al., 2008). Many classification systems of aerial habitats have been proposed (e.g. Kolbe, 1932; Petersen, 1935; Ettl and Gärtner, 1995). Patrick (1977) argues for the recognition of two groups: moist aerial habitats and dry aerial habitats.

An aerial habitat is a more stressful environment than an aquatic habitat (Patrick, 1977; Johansen, 2010). Johansen (2010) even describes these types of habitats as harsh and limiting in several respects. One important factor in aerial habitats is moisture availability and how desiccation resistant the taxa are. In a study from Subantarctica, Van de Vijver and Beyens (1999) show that species richness is closely related to the degree of moisture; dry habitats will contain fewer species than a wet habitat. Van de Vijver and Beyens (1997) further describe how the size of *Pinnularia borealis* Ehrenberg diminishes in dryer habitats. Temperature extremes are another important limiting factor in aerial habitats (Johansen, 2010), and water conductivity and pH affect diatom species composition (Fránková et al., 2009). Type of substrate influences the diversity of diatom communities. For example, plain rock faces or rock faces with mosses will be inhabited by different diatom flora. Additionally, many aerial diatoms only tolerate moderate levels of nitrogen (Johansen, 2010).

AREA OF INVESTIGATION

Kungsträdgården metro station is located in Norrmalm, Stockholm, Sweden (Fig. 1). The exits are situated about 150 meters from the Baltic Sea. The station opened in 1977 and is the end station for metro line 10 and 11 (Alfredsson et al., 2000). The station is built in granite, “Stockholm granite”, which is about 1.8 Ga (Ivarsson and Johansson, 1995). Kungsträdgården is the deepest of all metro stations in Stockholm and is located 29.3 meters below sea level and approximately 34 meters below ground level (Alfredsson et al., 2000). Ulrik Samuelson, the artist who designed the station, aimed to create an “underground cave garden” (Alfredsson et al., 2000). This resulted in the walls of Kungsträdgården metro station not being covered with concrete, which is the case of most other subsurface metro stations in Stockholm. The station is illuminated with artificial light and there are local occurrences of seeping water on the walls. Associated with the seeping water secondary minerals, speleothems, are formed as flowstones, coralloids and stalactites. Kungsträdgården metro station houses a complete ecosystem with cyanobacteria, diatoms and mosses as primary producers (Ivarsson et al., 2013). The top predator in this ecosystem is the spider *Lessertia denticulis* Simon, a species first reported from Sweden from this locality (Kronstedt, 1992).

MATERIAL AND METHODS

Diatom preparation and analysis

Three samples from Kungsträdgården metro station were collected on 5 November 2012 (Fig. 2). A spoon

Fig. 1. Location of Kungsträdgården metro station in Stockholm.

Fig. 2. Map of Kungsträdgården platform showing sampling sites K1, K3 and K7.

and a spatula were used to collect material from the walls of the platform. The sampling equipment was cleaned between each sampling site using water and paper tissues. For cleaning, samples were put in beakers and 25 ml of 30% hydrogen peroxide (H_2O_2 ; for the oxidation of organic matter) and 25 ml of 10% hydrochloric acid (HCl; to remove metal salts and carbonates) was added. The samples were then put on a hotplate where they were boiled for approximately two hours. When all the organic matter was oxidized, the samples were rinsed in distilled water six times and then, using a pasteur pipette, approximately 0.2 ml of the cleaned samples were dropped onto glass coverslips. After 24 hours in room temperature the diatoms had settled and the water evaporated and the coverslips were mounted onto permanent microscope slides using Naphrax™.

The samples were studied using a Leitz orthoplan light microscope at 1000x using oil immersion. First investigations were conducted thoroughly, and along transects, with the aim to identify all diatoms to species level. After identification, counting was carried out along transects, according to the method described by Schrader and Gersonde (1978). At least 400 valves were counted in every sample. The diatom flora by Krammer and Lange-Bertalot (1986-1991) was routinely used for the identification of species, but other floras were also used, e.g. Cleve-Euler (1951), Hustedt (1930) and Patrick and Reimer (1966). For nomenclature issues the website Algaebase was consulted (Guiry and Guiry, 2013). Results from light microscopy studies were documented using an Olympus BX51 microscope and an Olympus DP71 camera. The images were cropped using the software cellSens Dimensions.

For Scanning Electron Microscopy (SEM), cleaned samples were air-dried on carbon tape, placed on stubs. The samples were coated with a thin layer of gold (20 seconds) using an Agar high resolution sputter coater. The SEM investigations were carried out using the microscope Oxford Instruments model 6853, and the software Pc-SEM. Both the light microscope images and the SEM images were used to aid species identification.

ESEM analysis

An XL30 environmental scanning electron microscope (ESEM) with a field emission gun (XL30 ESEM-FEG) was used to analyse the minerals and the diatom ooze. The ESEM was equipped with an Oxford x-act energy dispersive spectrometer (EDS), backscatter electron detector (BSE) and a secondary electron detector (SE). The acceleration voltage was 20 or 15 kV depending on the nature of the sample and the instrument was calibrated with a cobalt standard. Peak and element analyses were made using INCA Suite 4.11 software.

RESULTS

The diatom flora in Kungsträdgården metro station

Altogether 12 species are documented from Kungsträdgården metro station (Table 1). Relevant synonyms are mentioned in Table 1 and in the discussion; for more detailed nomenclatural information, see the webpage <http://www.algaebase.org>. All identified taxa are pennate diatoms and have at least one raphe. Size and morphology of reported diatoms conform to ranges and descriptions in Krammer and Lange-Bertalot (1986-1991), unless otherwise is stated below.

Sample K1

Sample K1 consisted of a “calcareous diatom ooze” (Fig. 3) that occur in depressions (~1-2 cm) of coralloid speleothems. The composition of the speleothems were analysed by ESEM/EDS and consists of $CaCO_3$ (calcite or aragonite) and the diatom ooze of a calcareous mix with traces of Si, Mg, and S (Table 2; Fig. 4). Eight species were identified in this sample. *Diademsis contenta* (relative abundance, $ra=44.2\%$) (Fig. 5d), *Pinnularia appendiculata* ($ra=20.5\%$) (Fig. 5h), *Nitzschia amphibia* ($ra=19.8\%$) and *Grunowia sinuata* ($ra=12.7\%$) (Fig. 5j) were dominating in the sample. Species present at a lower abundance in this sample are *Cymbella laevis* ($ra=1.9\%$) (Fig. 5g), *Diademsis perpusilla* ($ra=0.5\%$) (Fig. 5e-f), *Halimophora normanii* ($ra=0.2\%$) (Fig. 5i) and *Caloneis cf. aerophila* ($ra=0.2\%$) (Fig. 5b).

Table 1. Taxa found in Kungsträdgården and their relative abundance (%).

Taxon	Notes	K1	K3	K7
<i>Caloneis</i> cf. <i>aerophila</i> Bock		0.2	1.5	11.4
<i>Caloneis</i> cf. <i>bacillum</i> (Grunow) Cleve		---	---	0.5
<i>Caloneis</i> sp.	Specimens notably smaller than the normally reported size range	---	0.4	1.4
<i>Cymbella laevis</i> Nägeli		1.9	---	3.6
<i>Diademesmis contenta</i> (Grunow ex Van Heurck) D.G. Mann	Synonym: <i>Navicula contenta</i> Grunow ex Van Heurck	44.2	---	37.7
<i>Diademesmis perpusilla</i> (Grunow) D.G. Mann	Synonyms: <i>Navicula perpusilla</i> Grunow, <i>Navicula gallica</i> var. <i>perpusilla</i> (Grunow) Lange-Bertalot, <i>Diademesmis gallica</i> var. <i>perpusilla</i> (Grunow) Lange-Bertalot	0.5	---	---
<i>Diploneis ovalis</i> (Hilse) Cleve		---	---	8.9
<i>Grunowia sinuata</i> (Thwaites) Rabenhorst		12.7	86.6	2.2
<i>Halamphora normanii</i> (Rabenhorst) Levkov	Synonym: <i>Amphora normanii</i> Rabenhorst	0.2	1.1	---
<i>Navicula</i> sp.		---	---	0.2
<i>Nitzschia amphibia</i> Grunow		19.8	9.6	33.8
<i>Pinnularia appendiculata</i> (C. Arardh) Cleve		20.5	0.7	0.2

Sample K3

Sample K3 did not consist of calcareous material, but of a dark brown diatom algae mat. Six species were identified. *Grunowia sinuata* dominated in the sample (ra=86.6%) (Fig. 5j), together with *Nitzschia amphibia* (ra=9.6%). *Caloneis* cf. *aerophila* (ra=1.5%) (Fig. 5b), *Halamphora normanii* (ra=1.1%) (Fig. 5i), *Pinnularia appendiculata* (ra=0.7%) (Fig. 5h) were also documented from sample K3. Further, an unusually small and unidentified *Caloneis* species (ra=0.4%)

Fig. 3. Local occurrence of “calcareous diatom ooze” on coralloid speleothems found in Kungsträdgården metro station.

Fig. 4. ESEM image of the calcareous ooze.

(Fig. 5c) was found in this sample. It is approximately 5 μm long and 2.5 μm wide. Striae are 5 in 2 μm, which gives 25 in 10 μm.

Sample K7

Like sample K1, sample K7 consisted of a “calcareous diatom ooze” (Fig. 3) that occur in depressions (~1-2 cm) of coralloid speleothems. Ten species were identified in sample K7. *Diademesmis contenta* was dominating (ra=37.7%) (Fig. 5d), together with *Nitzschia amphibia* (ra=33.8%), *Caloneis* cf. *aerophila* (ra=11.4%) (Fig. 5b) and *Diploneis ovalis* (ra=8.9%) (Fig. 5k). Species found in less abundance in this sample were *Cymbella laevis* (ra=3.6%) (Fig. 5g), *Grunowia sinuata* (ra=2.2%) (Fig. 5j), the small unidentified *Caloneis* species (ra=1.4%) (Fig. 5c), *Caloneis* cf. *bacillum* (ra=0.5%) (Fig. 5a), *Pinnularia appendiculata* (ra=0.2%) (Fig. 5h), and *Navicula* sp. (ra=0.2%).

DISCUSSION

The diatom flora of Kungsträdgården in comparison with other cave environments

Cave entrances are known to be inhabited by a flora of cyanobacteria, algae (e.g. chlorophyta, chrysophyta and diatoms), mosses, ferns and angiosperms (Lundberg, 2011; Mulec, 2012). Algae mats often cover large parts of cave walls (Roldán and Hernández-Mariné, 2009). The moist cave environment, in which temperature typically is relatively stable, facilitates diatom growth (Palmer, 2007), and while decreasing light eventually will become a limiting growth factor in a cave, it is typically available in sufficient intensity near the cave entrance. The diatom species richness in Kungsträdgården was low compared to most cave inventories (e.g. St. Clair and Rushforth, 1976; St.

Table 2. EDS analysis of speleothems and the associated calcareous ooze.

	CaCO ₃	Ooze	Ooze	Ooze
C	11.40	14.73	16.90	12.80
O	50.76	54.15	57.90	43.27
Mg		0.50		0.58
Si		0.39	0.76	0.58
S		0.43		
Ca	37.85	29.80	24.44	42.77
Total	100.00	100.00	100.00	100.00

Fig. 5. Species found in Kungsträdgården samples. a) *Caloneis* cf. *bacillum* (scale bar = 10 µm); b) *Caloneis* cf. *aerophila* (scale bar = 10 µm); c) *Caloneis* species (scale bar = 5 µm); d) *Diadsmis contenta* (scale bar = 5 µm); e-f) *Diadsmis perpusilla* (scale bar = 5 µm); g) *Cymbella laevis* (scale bar = 10 µm); h) *Pinnularia appendiculata* (scale bar = 10 µm); i) *Halamphora normanii* (scale bar = 10 µm); j) *Grunowia sinuata* (scale bar = 10 µm); k) *Diploneis ovalis* (scale bar = 10 µm); l-m) SEM images of *Caloneis* cf. *aerophila* (scale bar = 5 µm in l and 10 µm in m).

Clair et al., 1981; Pouličková and Hašler, 2007). This finding fits the commonly observed pattern that species diversity of Lampenfloras is poor in comparison with cave entrances characterized by sun light (Mulec et al., 2008; Llop et al., 2012; Mulec, 2012). However, the Lampenflora in Kungsträdgården is represented by 12 diatom species, and this is a higher species richness than in most other studies of Lampenfloras (e.g. Pouličková and Hašler, 2007; Smith and Olson, 2007; Mulec et al., 2008; Abdullin, 2011). Conceivably, this can be explained by the urban environment, from which the Kungsträdgården samples were taken. Compared to other cave environments, Kungsträdgården is more frequently visited by humans and that may contribute to dispersal. The metro station is further illuminated 24 hours a day which is distinctly more than a show cave that might be illuminated a few hours a day or a few days a week.

Ecology of selected taxa

Diademesmis perpusilla (Grunow) D.G. Mann. Synonyms: *Navicula perpusilla* Grunow, *Navicula gallica* var. *perpusilla* (Grunow) Lange-Bertalot, *Diademesmis gallica* var. *perpusilla* (Grunow) Lange-Bertalot. Fig. 5e-f.

Diademesmis perpusilla is only found in sample K1, and at a low relative abundance. According to Krammer and Lange-Bertalot (1986) it is often found on moist rocks, mosses and in soils. All species of *Diademesmis* are considered to be aerophilic (Spaulding and Edlund, 2009). *Diademesmis perpusilla* is characteristic of environments with considerable reduction in light intensity, for example in caves (Krammer and Lange-Bertalot, 1986). Species of the genus *Diademesmis* can also produce alternative frustules where the raphe slits are filled with silica. Due to this, these specimens can be confused with e.g. taxa of the fragilarioid genera (Round et al., 1990). *Diademesmis perpusilla* is reported from caves in e.g. Canada (Lauriol et al., 2006), United States (St. Clair and Rushforth, 1976; St. Clair et al., 1981), Belgium (Garbacki et al., 1999) and Slovenia (Mulec et al., 2008).

Diademesmis contenta (Grunow ex Van Heurck) D.G. Mann. Synonym: *Navicula contenta* Grunow ex Van Heurck. Fig. 5d.

Diademesmis contenta occurs in high abundance in the calcareous ooze samples (K1 and K7) of Kungsträdgården. This species is often found on rocks and mosses where water is seeping (Krammer and Lange-Bertalot, 1986). *Diademesmis contenta* is also one of few diatom species, which can live on dry rocks (Patrick, 1977). Like *D. perpusilla*, *D. contenta* is often found in environments with reduced light intensity (Krammer and Lange-Bertalot, 1986) and has previously been reported from caves in e.g. Canada (Lauriol et al., 2006), United States (St. Clair and Rushforth, 1976; St. Clair et al., 1981; Dayner and Johansen, 1991), Czech Republic (Pouličková and Hašler, 2007), Belgium (Garbacki et al., 1999), Slovenia (Mulec et al., 2008) and as Lampenflora in Kentucky, United States (Smith and Olson, 2007), Russia (Abdullin, 2011) and Malta (Llop et al., 2012).

Pinnularia appendiculata (C. Agardh) Cleve Fig. 5h.

Pinnularia appendiculata is present in all three samples, but is only abundant in sample K1 where it represents more than a fifth of the diatom community. It is an aerophilic species and can be found for example on wet mosses and rocks (Krammer and Lange-Bertalot, 1986). This species has been documented from a cave in Arizona, United States (Johansen et al., 1981).

Diploneis ovalis (Hilse) Cleve Fig. 5k.

Diploneis ovalis is only found in sample K7 where it comprises about 1/10 of the diversity. It is a common epipelagic diatom (Krammer and Lange-Bertalot, 1986), previously reported from a cave in Spain (Roldán et al., 2004).

Cymbella laevis Nägeli Fig. 5g.

Cymbella laevis is found in the calcareous samples (K1 and K7). The species is associated with oligotrophic calcareous waters, for example in karst landscapes, particularly on mosses and rocks (Krammer and Lange-Bertalot, 1986).

Caloneis cf. *aerophila* Bock Fig. 5b.

Caloneis aerophila is a rare species, associated with wet rocks (Krammer and Lange-Bertalot, 1986). Nevertheless, it makes up 11% of the taxa in sample K7, and is also found in the other samples. Species identification in this genus is problematic and we have only tentatively assigned certain diatoms to *C. aerophila*. Characters overlap between *C. aerophila* and *C. bacillum*, a problem that exists for several *Caloneis* species (Krammer and Lange-Bertalot, 1986). To our knowledge *C. aerophila* has not been reported from Sweden before, but it was not described until 1963 and it may have been identified as another species, for example *C. bacillum*, by early diatomologists.

Caloneis sp. Fig. 5c

The unusually small *Caloneis* specimens found in samples K7 and K3 could be small forms of *C. aerophila* or *C. bacillum*. If so, our findings would expand the known size range of these species (but see Kupe et al. 2010, who reported a small *Caloneis* species in a karst lake in Albania). Diatoms successively diminish in size as a natural consequence of vegetative reproduction and in cultivation, minute, round or misshaped valves are sometimes observed when cells fail to undergo the subsequent phase of auxospore formation (normally associated with sexual reproduction). However, such small or misshaped valves are rarely seen in natural diatom communities (Round et al., 1990), and the small specimens found here could instead represent a new, not yet described species of *Caloneis*. Both these scenarios are plausible, but a more expanded and detailed study (preferably with SEM) of this taxon is needed.

Halammphora normanii (Rabenhorst) Levkov.

Synonym: *Amphora normanii* Rabenhorst. Fig. 5i.

Halammphora normanii is found in samples K1 and K3 at low relative abundances. This is an aerophilic

species, mainly reported from wet mosses and on rocks where water is seeping (Krammer and Lange-Bertalot, 1986). The only previous report of this species in Sweden is from a paleolimnological study of small lakes, which were isolated from Lake Vänern during the Holocene (Risberg et al., 1996). It has also been reported from caves in Italy (Giordano et al., 2000).

Microhabitat and distribution patterns in the metro station

Dispersal of diatoms into Kungsträdgården metro station is most probably accomplished by air. Diatoms have been shown to be able to disperse over long distances by air (Spaulding et al., 2010), but are not known to migrate through micro-fractures in rock. The platform is not located under the Baltic Sea, which also contradict migration through cracks in the rock. It is also likely that the constant flow of people at the metro station might increase the chances and speed of introduction of new species to the station.

A spatial distribution of different communities of diatoms, characterized by different species composition, could be observed in Kungsträdgården metro station. This indicates a heterogeneous habitat providing different microhabitats, similar to some natural subterranean habitats (Culver and Pipan, 2009). Since no rapheless diatoms were found in any of the samples, motility seems to be important in the microhabitats of the calcareous ooze and the brown algae mat. However, there are no indications of an ability of the diatoms to move between the microhabitats on the wall; the distances between them are too great and the lack of coherent water seeping makes it impossible for the diatoms to migrate. Samples K1 and K7 are rather similar in their species composition, both dominated by *Diadesmis contenta* and *Nitzschia amphibia*. Both K1 and K7 are calcareous ooze samples and they have higher species richness than the brown algae mat of sample K3. This is in line with other studies of diatom species richness, which show a positive correlation with pH, calcium and conductivity (Pouličková et al., 2004, Fránková et al., 2009). There are however differences between K1 and K7, such as *Pinnularia appendiculata* being abundant in K1 and the presence of *Diploneis ovalis* in K7 but not in K1.

None of the few species of diatoms known to be obligatory heterotrophs were found in this study. The diatoms in Kungsträdgården are primary producers, utilizing the artificial light from the illumination. They form, together with e.g. cyanobacteria and the moss *Eucladium verticillatum* (Brid.) Bruch & Schimp, the primary foundation of the food web in the metro station.

The speleothems – a result of biogenic speleogenesis?

The formation of coralloid speleothems was studied in Togawa-Sakaidani-do Cave, Japan, by Kashima et al. (1987). This cave has developed in deposits of Quaternary pyroclastic flows and both the bedrock and the speleothems are rich in silica. Kashima et al. (1987) suggests that the growth of these speleothems is triggered by the activities of diatoms (*Melosira* spp.). Diatoms have also been shown to influence calcite

precipitation in travertine crusts (Pentecost, 1998). This is done by depositing calcium carbonate crystals in the secreted mucilage (Pouličková and Hašler, 2007).

Nothing in the results of Kungsträdgården indicates that the diatoms trigger the growth of the speleothems found. However, the calcareous ooze (samples K1 and K7) are dominated by diatoms and it is likely that the diatoms are involved in the formation of this microhabitat. Diatoms are known to dissolve carbonates by excreting organic acids, thus, it is possible that they are actively involved in the persistence of the ooze (Brehm et al., 2005). Clearly, the calcareous ooze is a small and specialized niche in the ecosystem of the walls at Kungsträdgården metro station.

CONCLUSIONS

The Lampenflora of Kungsträdgården metro station is dominated by aerophilic taxa and is represented by 12 diatom species, a relatively high species richness compared to other studies of Lampenflora. All identified diatoms are autotrophic and pennate. Dispersal of diatoms into Kungsträdgården has probably occurred by air. It is likely that the diatoms are involved in the formation of the calcareous ooze found on the walls of Kungsträdgården metro station.

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