Lichens and bryophytes on shaded sandstone outcrops used for rock climbing in the vicinity of Göttingen (southern Lower Saxony, Germany)

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Abstract: THIEL, H. & SPRIBILLE, T. 2007. Lichens and bryophytes on shaded sandstone outcrops used for rock climbing in the vicinity of Göttingen (southern Lower Saxony, Germany). Herzogia **20**: 159–177.

Sandstone rock formations are assuming increasing importance for sport rock climbing activities in central Germany, but little is known of their cryptogamic flora. We inventoried cryptogams on 27 natural sandstone outcrops and three historical quarries in the vicinity of Göttingen as part of a long-term land use planning effort. Every single rock outcrop and quarry supported at least one red-listed cryptogam species. Several noteworthy species were documented in the survey. Among lichens, the rare central European endemic *Endocarpon latzelianum* is new to Germany, while seven species are new to Lower Saxony (*Agonimia* cf *tristicula*, *Arthonia endlicheri*, *Aspicilia moenium*, *Botryolepraria lesdainii*, *Lepraria crassissima*, *Micarea myriocarpa* and *Verrucaria dolosa*) and five species presumed extinct are re-confirmed as present in Lower Saxony (*Cresponea premnea*, *Lecania cuprea*, *Lecania sylvestris*, *Leptogium teretiusculum* and *Opegrapha calcarea*). Among bryophytes, *Conocephalum salebrosum* is reported new to Lower Saxony and *Tetrodontium brownianum* is reported for the first time since 1902. Conflicts between rock climbing and cryptogam assemblages occur primarily on dry walls which are the preferred habitats of certain crustose lichens and the preferred sites for sport climbing. The high number of red-listed and newly discovered species underlines the significance and conservation-worthiness of the Göttingen sandstone outcrops. Lichens and bryophytes are key to assessing microhabitat values for planning efforts in these ecosystems.

Zusammenfassung: THIEL, H. & SPRIBILLE, T. 2007. Flechten und Moose an beschatteten Buntsandstein-Kletterfelsen in der Umgebung von Göttingen (Niedersachsen). Herzogia **20**: 159–177.

Sportklettern erfreut sich zunehmender Beliebtheit. Bei einer Begutachtung der Flechten- und Moosflora von Buntsandsteinfelsen im Hinblick auf stattfindende und mögliche Konflikte mit Klettersportaktivitäten haben wir 27 natürliche Felsen und drei ehemalige Steinbrüche in der Umgebung von Göttingen untersucht. An jedem der untersuchten Felsen und Steinbrüche kamen Arten der Roten Listen vor. Mehrere bemerkenswerte Arten wurden festgestellt: Die in Zentraleuropa endemische Flechte *Endocarpon latzelianum* ist neu für Deutschland. Sieben Flechtenarten sind neu für Niedersachsen (*Agonimia* cf *tristicula*, *Arthonia endlicheri*, *Aspicilia moenium*, *Botryolepraria lesdainii*, *Lepraria crassissima*, *Micarea myriocarpa* and *Verrucaria dolosa*), fünf weitere galten im Bundesland als ausgestorben oder verschollen (*Cresponea premnea*, *Lecania cuprea*, *Lecania sylvestris*, *Leptogium teretiusculum* und *Opegrapha calcarea*). Das erst kürzlich beschriebene Lebermoos *Conocephalum salebrosum* wird erstmals für Niedersachsen angegeben, das Laubmoos *Tetrodontium brownianum* wurde nach über 100 Jahren wiedergefunden. Konflikte zwischen Klettersportaktivitäten und Kryptogamenvorkommen bestehen vor allem an trockenen Wänden. Hier besteht Deckungsgleichheit zwischen den bevorzugt zum Klettern ausgewählten Felseigenschaften und den Habitatansprüchen bestimmter gefährdeter Krustenflechtenarten. Die hohe Zahl von Neufunden und Rote Liste-Arten unterstreicht die besondere Bedeutung und Schutzwürdigkeit der Buntsandsteinfelsen in der Region Göttingen. In diesen Lebensräumen fällt Flechten und Moosen eine Schlüsselrolle bei der Bewertung von Nutzungen und Beeinträchtigungen zu. Sie müssen in Zukunft bei Planungen berücksichtigt werden.

Key words: *Acrocordia*, conservation, crustose, cryptogam, *Endocarpon*, *Lepraria*, threat assessment.

Introduction

The sandstone outcrops in the vicinity of Göttingen (central Germany, c. 51°25'N–51°34'N and 10°00'E–10°05'E) have attracted the attention of lichenologists and bryologists since the 18th century. The first accounts of lichens and bryophytes in the surroundings of Göttingen date back to WEIS (1770). Aside from a few individual records, the details provided by WEIS do not suffice to characterize the complete lichen composition of the Göttingen sandstone formation in the 18th century. WEIS' account does, however, paint a picture of a luxurious epiphytic macrolichen flora that almost completely disappeared with the increase in SO_2 deposition since the industrial revolution. In the intervening 237 years, records of lichens from the Göttingen area have been scattered throughout the literature, but there have never been reproducible baseline surveys.

The bryophyte flora is somewhat better documented. Here, too, WEIS (1770) provided a useful early account. This was followed by contributions of several other authors of the late 18th century, such as SCHRADER (1795–1798) and HOFFMANN (1796). An inventory of the bryophyte flora of the region around Göttingen, including a detailed list of new finds and a complete assessment of the literature to date, was provided by QUELLE (1902). The work of QUELLE was used by GLÄSER (1994) as a baseline against which to compare changes in the bryophyte flora over time in forests over sandstone and limestone near Göttingen.

The first documented sport climbing on sandstone outcrops around Göttingen can be dated back to the 1950s. Starting in the 1970s, favoured climbing routes began to be outfitted with permanent rope hooks drilled into the rock surface. The majority of routes are classified as difficult by rock climbers, but this has not hindered climbing activities or the establishment of new climbing routes. In the last decade, bouldering, i.e., rope-free climbing of outcrop faces close to the ground, has emerged as a significant activity in addition to sport climbing in which the climber is secured with ropes. The popularity of outcrops and routes varies greatly. Several outcrops are climbed regularly, others rarely. In addition, there are many rock formations that are unsuited for climbing. It is anticipated that climbing activities and associated tourism will increase in the future.

In the autumn of 2005 we were commissioned to survey the lichen and bryophyte floras of selected sandstone outcrops in the vicinity of Göttingen. The objective was to identify the presence or absence of red-listed cryptogam species on outcrops with rock climbing activities. The results formed the basis for an assessment and subsequent management decision for the Landkreis (county) of Göttingen in collaboration with the state forestry authority and interest groups representing both conservationists and rock climbers. In addition to our report, the wider assessment took both archaeological (GROTE 1994) and faunistic aspects into account. Despite the long tradition of cryptogamic research in Göttingen, our study was the first systematic survey of lichens and bryophytes on sandstone outcrops in northern Germany.

Here we present the lichen and bryophyte flora of the investigated outcrops with emphasis on some of the more noteworthy finds. We will highlight current and potential impacts and threats from rock climbing activities, in the hope that this information will be useful in designing future assessments in Germany and other regions.

Materials and Methods

Study Area

The studied outcrops are located in the Landkreis of Göttingen in southern Lower Saxony, near the villages of Reinhausen, Bremke, Ischenrode, Benniehausen, Waake and Eddigehausen in

the Reinhäuser Wald and Göttinger Wald. With over 2000 individual sandstone outcrops, the region has one of the highest densities of exposed rock in the central German uplands. The outcrops and cliffs belong to the Solling series of the middle coloured sandstone formation (Buntsandstein, sm2; NAGEL & WUNDERLICH 1976). The rocks were often excavated in the past for construction materials; today, most quarries are abandoned. The climate is suboceanic and characterized by a low amplitude of mean monthly temperatures and relatively low precipitation (Göttingen weather station, elev. 155 m s.m.: mean annual precipitation 607 mm; mean annual temperature 8.5 °C; mean annual temperature fluctuation >17 °C; WALTER & LIETH 1967). The studied outcrops are situated at altitudes of 200–300 m s. m. in areas of slightly higher precipitation and lower mean temperatures than Göttingen. All studied rock outcrops were in forests and did not protrude above the forest canopy; most of them are thus shaded or partially shaded for most of the summer.

In total, 27 natural outcrops and three abandoned quarries of varying sizes, heights and expositions were surveyed (Table 1). The studied outcrops were selected by the project commissioners primarily based on rock climbing interests. As rock climbers prefer dry, relatively exposed rock faces, the selection is not representative of sandstone outcrops in the Göttingen region as a whole, but instead emphasises an outcrop type with comparatively high, often overhanging, dry walls, limited rain exposure and often somewhat base-rich conditions. Such outcrops are uncommon due to the shading of most outcrops by trees and the high water retention capacity of sandstone, leading to prolonged periods of moisture on rock surfaces via capillary action (GLÄSER 1994). As rain- and moisture-induced weathering can alter the chemical composition of sandstone through leaching of carbonates, rain-sheltered rock faces tend to be both dry and base-rich. Nonetheless, all outcrops also support rain-exposed, highly acidic and moist portions. The degree of use by rock climbers varies greatly, with some outcrops climbed frequently and others only rarely.

Field surveys

Complete lists of bryophyte and lichen species were assembled for each outcrop. In addition to non-vascular cryptogams, prothalli of the fern *Trichomanes speciosum* Willd. were included in the survey owing to the status of the species in Appendix 2 of the European Union Habitats Directive (PETERSEN et al. 2003) and its close association with bryophytes and lichens (only prothalli are known from continental Europe). The tops of outcrops and vertical walls were surveyed where necessary by rappelling while other parts were surveyed from the ground. Only substrates specific to the rock outcrops, i.e. the rock surface and overgrowing mosses or patches of humus, were surveyed.

Species identification

All specimens not identifiable with certainty to species were collected and identified in the laboratory using standard light microscopic methods. Noteworthy bryophyte samples were retained in the collection of the first author (hb. Thiel), while lichen specimens, to the extent they were herbarium-worthy, are deposited in B and/or BG unless otherwise noted. Collecting was kept to a minimum but the removal of small pieces was unavoidable for identification in many cases; in total, 414 lichen specimens were collected. Of these approximately 150 lichen samples including almost all *Lepraria* specimens were studied using thin layer chromatography (CULBERSON 1972; CULBERSON & JOHNSON 1982). Taxonomy and nomenclature follow KOPERSKI et al. (2000) for bryophytes and SCHOLZ (2000) for most lichens; red-listed species follow KOPERSKI (1999) and HAUCK (1992).

Table 1: List of studied outcrops in the vicinity of Göttingen (numbered 1–30) with German topographic map number (MTB, Messtischblatt), Gauss-Krüger coordinates (r- and h-values), and gross attributes of each outcrop. Aspect, height of outcrop and popularity for climbing is based on assessments from local climbers (modified from Wiechmann et al., unpubl.).

nr.	MTB	r value	h value	altitude [m s.m.]	outcrop height [m]	aspect	popularity for climbing	additional information
1	4526/31	3571500-570	5700910-960	290	8	SW	low	
2	4526/31	3571570	5700430	290	8	NW, NE	not used	
3	4526/31	3571330	5700530	290	8	NW	low	
4	4525/24	3568080	5703370	220	8	SW	medium	
5	4525/24	3568040	5703020	230	10	SW	medium	
6	4526/13	3570000	5703990	250	9	NW	low	
7	4526/13	3570110	5703950	250	7	S	low	
8	4526/13	3570120	5703940	250	9	S	high-medium	
9	4526/13	3570200	5703930	250	16	S	high	
10	4526/13	3570050	5703620	270	10	SE	low	
11	4526/13	3570520-540	5702920-970	270	12	SE	medium-low	
12	4526/13	3571500	5702520	280	8	all	low	natural tower
13	4526/13	3571510	5702280	280	9	SE	high-medium	
14	4526/13	3571490	5702250	280	9	S	medium	
15	4526/13	3571480	5702240	280	13	S, E	high-medium	
16	4526/13	3571460	5702240	280	8	S	medium	
17	4526/13	3571450	5702230	280	8	S, W, N	low	
18	4526/13	3571420	5702210	280	8	S	medium	
19	4526/13	3571400	5702200	280	8	S	medium	
20	4526/13	3571390	5702200	280	8	all	low	
21	4526/11	3571200	5706900	210	15	S, W	low	abandoned quarry
22	4526/11	3571620	5707050	240	8	SE	low	
23	4526/12	3573440	5707120	240	10	W	medium	
24	4526/12	3573450	5707000	230	18	S	medium-low	abandoned quarry
25	4426/14	3574660	5714680	250	8	S	medium-low	
26	4426/14	3574840	5714700	260	8	S	low	
27	4426/14	3574860	5714700	260	9	S	low	
28	4426/14	3574940	5714700	260	12	S	medium-low	
29	4325/43	3566300	5719760	270	8	NW	low	
30	4325/43	3565960	5718900	210	22	E, S, W	high-medium	abandoned quarry

Results

Seventy-seven species of lichens and 114 species of bryophytes (27 liverworts, 87 mosses) were documented on the 30 outcrops. The average outcrop supported 36 species of cryptogams, with as few as 11 species or as many as 73 found on a single outcrop. We found an average of 11.8 lichen species, 20.7 moss and 4.0 hepatic species per outcrop (Table 2).

One lichen species, *Endocarpon latzelianum* is new to Germany; another species discovered during this survey, *Lepraria obtusatica*, is discussed by SPRIBILLE & TØNSBERG (2007). A further seven lichen taxa (*Agonimia* cf. *tristicula*, *Arthonia endlicheri*, *Aspicilia moenium*, *Botryolepraria lesdainii*, *Lepraria crassissima*, *Micarea myriocarpa* and *Verrucaria* aff. *dolosa*) and one bryophyte species (*Conocephalum salebrosum*) are new for Lower Saxony. We rediscovered five lichen and one bryophyte species during our survey previously considered extirpated from Lower Saxony: *Cresponea premnea*, *Lecania cuprea*, *Lecania sylvestris*, *Leptogium teretiusculum*, *Opegrapha calcarea* and *Tetrodontium brownianum*. Red-listed species or species new for Lower Saxony or Germany were found on each of the 30 outcrops and quarries investigated.

Observations on habitat niches

Lichen and bryophyte species occur in one of three broadly defined niche types on the studied rock outcrops: 1) moist habitats, especially rain-exposed surfaces or deeply shaded walls; 2) dry habitats, found in particular on underhangs with limited rain exposure, more rarely on sun-exposed walls; and 3) deep, dark crevices. The majority of bryophytes are found in rain-exposed or moist habitats. Dry habitats are less commonly colonized by bryophytes and consist of a combination of bare rock and various lichen species. Rock crevices and recesses have a specific flora containing species such as *Botryolepraria lesdainii*, *Lepraria crassissima*, *L. incana*, *L. lobificans*, *Calypogeia integristipula*, *Heterocladium heteropterum*, *Pseudotaxiphyllum elegans* and the rare *Tetrodontium brownianum*. Prothalli of the fern *Trichomanes speciosum* are restricted to the darkest recesses. The tops of cliffs usually do not support a special cryptogamic flora except for the occurrence of *Dicranum spurium*, a typical species of such habitats, which was found once. Although some cliff 'heads' were obviously impacted by climbing and trampling by hikers, it was not always apparent that this was the sole reason for the paucity of bryophyte and lichen specialists.

Sandstone outcrops almost invariably exhibit greater species richness than the abandoned quarries we surveyed. Sandstone outcrops are highly differentiated into vertical walls and ledges as well as crevices, shallow caves, cracks and overhangs, offering a large diversity of microhabitats with differences in light intensity, substrate and air moisture, rain exposure and calcium content/external encrustation. They offer more structural features than abandoned quarries which consist mainly of vertical, smooth walls. Abandoned quarries can however support very rare species: two of the three occurrences of *Endocarpon latzelianum*, a new lichen for Germany, were in abandoned quarries.

Cryptogam vegetation along climbing routes

Approximate climbing routes on all outcrops were provided on maps by the project commissioners, and most popular established routes were easily recognizable in the field by the presence of rope-hooks, abrasion of the sandstone surface, and the white colouring of grip holds through use of chalk by climbers (Fig. 1). Rock faces used for climbing or bouldering were almost invariably dry and more or less free of bryophytes. Naturally dry vertical walls are used for rock climbing wherever they are found, so there are no 'natural' control outcrops on which we could have assessed what lichen and bryophyte vegetation might be like in the absence of climbing.

Fig. 1: 'Wellenwand', one of the studied outcrops most preferred by rock climbers (Leuchtetal near Bremke; photo H. Thiel, February 2007). White markings on the rock are bouldering gripholds treated with chalk.

Relatively undisturbed vegetation can however be found on parts of walls that are less accessible or attractive for climbing, such as on lower vertical walls unsuitable for bouldering and away from designated climbing routes. The cryptogam vegetation here is dominated by crustose lichens; bryophytes are rare or absent. Species typical of such habitats include *Acrocordia* sp., *Caloplaca citrina*, *Cresponea premnea*, *Lecanora dispersa*, *Lecanora* aff. *horiza*, *Opegrapha mougeotii*, and *Verrucaria* aff. *dolosa*. Some of the rarest species – including the above-mentioned *C. premnea* and *Lecanora* aff. *horiza*, as well as *Arthonia endlicheri*, *Endocarpon latzelianum*, *Lecania cuprea*, *Lecania sylvestris*, *Leptogium teretiusculum* and *Opegrapha calcarea* – occur exclusively on dry walls. Two other species, *Agonimia* cf. *tristicula* and *Leptogium teretiusculum*, occur only in and immediately next to two of the most popular climbing routes in the region. Only one bryophyte, *Conardia compacta*, appeared to be limited to climbed areas. Other bryophyte species are less in line with climbing activities; red-listed species growing in climbing routes usually occur also in other favourable habitats nearby.

Impacts of past and present climbing on cryptogams were evident in several cases. At one outcrop, a wire brush used to remove bryophytes and *Lepraria* mats had been left at the base of a cliff. On undisturbed parts of outcrops, small holes in dry rock faces are normally colonized by lichens: sheltered recesses are occupied by *Lepraria crassissima* or *L. lobificans*, the moss *Rhynchostegiella tenella* or more rarely *Arthonia endlicheri*, with the 'lips' of such holes often colonized by *Cresponea premnea*. Cryptogams are typically absent from such holes along climbing routes, where they serve as grip-holds. Species normally occupying flat, dry vertical surfaces on dry walls, such as *Opegrapha mougeotii* and *Acrocordia* sp., are directly impacted by abrasion of the rock surface and it is not uncommon to find places where lirellae or perithecia have been dislodged and thalli abraded by climbers.

Notes on new or noteworthy species

Several lichen and bryophyte species detected in our surveys represent new records or rediscoveries for Lower Saxony and/or Germany; many are rediscoveries or new species for the vicinity of Göttingen. In the following, we will briefly summarize some of the more noteworthy finds and explain their significance.

Table 2: Species found on all studied outcrops. For bryophytes and *Trichomanes*, a general abundance system was used, whereby 1 – rare, 2 – infrequent, 3 – common, 4 – abundant, and 5 – dominant; for lichens all data are presence/absence; v – supported by voucher, o – observed but not collected.

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Liverworts																															
Bazzania trilobata	*5*	1	2	2		1												3													
Blepharostoma trichophyllum	*1*		2																												
Calypogeia fissa	*1*	1																													
Calypogeia integristipula	*14*	3	3	3		2	3	2			3	2	2	2				2	3	2								2			
Calypogeia muelleriana	*6*	2	2			2						1	2	2																	
Cephalozia biscuspidata	*8*		4	4	3				2		3		3	2			2														
Cephalozia lunulifolia	*1*		2																												
Cephaloziella divaricata	*1*														2																
Chiloscyphus pallescens	*1*																								1						
Conocephalum conicum s.lat.	*2*		2																					2							
Conocephalum salebrosum	*1*										3																				
Diplophyllum albicans	*9*	3	2	4	3							2	2		2			2						2							
Harpanthus scutatus	*1*		2																												
Jamesoniella autumnalis	*1*																	3													
Jungermannia hyalina	*1*		1																												
Jungermannia leiantha	*1*		1																												
Lepidozia reptans	*12*	3	4			3		3	3	2	3	3					2	3		3				2							
Lophocolea bidentata	*2*		1								3																				
Lophocolea heterophylla	*10*		3	3		2	2				2	2	2					2								2				2	
Lophozia ventricosa	*2*		1																						2						
Metzgeria furcata	*15*	3				1		2	3	4	2											4	3	3	3	2	2		4	2	3
Nowellia curvifolia	*1*																	1													
Plagiochila porelloides	*5*		1				2															2	3							2	
Porella platyphylla	*4*											2										2	2							2	
Scapania nemorea	*7*		3				2					2	4		2		2	4													
Tritomaria exsecta	*1*		1																												
Tritomaria exsectiformis	*3*		2														1	2													
Mosses																															
Amblystegium serpens	*11*		3							2		2					2					2			2		2	2	2	2	3
Anomodon attenuatus	*5*																					3	4		2				3		3

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Anomodon longifolius	*1*																						2								
Atrichum undulatum	*8*	2	2			2	2				2	2								2				2							
Aulacomnium androgynum	*9*	2	3			2		3			3			2						3	3			2							
Brachythecium populeum	*9*	2					2					2										3	3	2	2				2		3
Brachythecium rutabulum	*18*		3	2		4	2		2		3	1	2					2	3	2	5	3	2	3	3					2	4
Brachythecium salebrosum	*3*		2			3														2											
Brachythecium velutinum	*14*	3	3	2		3			2	3		2								3			2	2	2	3				3	3
Bryoerythrophyllum recurvirostrum	*2*																												2		3
Bryum capillare	*11*	2				3		3	2												3	2		2	2		2		2		2
Bryum subelegans	*8*	2					2			2			2							2					2					2	3
Campylopus flexuosus	*16*	4	3			3		4	4	3	2	4		4	4	4	4	4		4				3				3			
Campylopus introflexus	*2*															2	2														
Campylostelium saxicola	*1*		1																												
Ceratodon purpureus	*2*							2						2																	
Conardia compacta	*1*														2																
Dicranella heteromalla	*25*	4	4	3	2	4	3		3	4	3	4	3	4	4		3	4	3	4		3	4	4		3		3	3	4	4
Dicranodontium denudatum	*1*		3																												
Dicranoweisia cirrata	*3*													2		2														2	
Dicranum flagellare	*2*																	2	1												
Dicranum fulvum	*7*		2	2			2			2	3	2	2																		
Dicranum majus	*3*		3	2		2																									
Dicranum montanum	*23*	3	3			2	3	5	3	3		5	4		4	3	3		3	3	4	2		4		3	4	3	3	2	2
Dicranum polysetum	*4*							3	2										2	2											
Dicranum scoparium	*24*	3	4	3		4	3	4	4		3		4	3	4	2		2	3	3			3	4	4	3	3	3	3	3	3
Dicranum spurium	*1*																								1						
Didymodon rigidulus	*8*																					2	2	2	2			2	2	2	3
Didymodon vinealis var. *flaccidus*	*4*									2		1													2						2
Encalypta streptocarpa	*1*																														2
Eucladium verticillatum	*1*																								1						
Eurhynchium hians	*7*		2			3			2			1								2				2	2						
Eurhynchium praelongum	*1*					2																									
Eurhynchium pulchellum var. *praecox*	*1*		2																												
Eurhynchium striatum	*4*					2					2										2	2									
Fissidens bryoides	*6*	3					2		2	2		2											2								2

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Fissidens dubius	*3*	3								2		2																			
Fissidens pusillus	*11*	2	2				2		2	2													3	3		2			2	2	2
Fissidens taxifolius	*3*																							2	2						3
Grimmia pulvinata	*1*																													1	
Grimmia trichophylla	*2*																												1	2	
Gymnostomum calcareum	*1*																								2						
Gyroweisia tenuis	*2*								2																2						
Herzogiella seligeri	*1*		1																												
Heterocladium heteropterum	*8*		3	2			2					2		2										2			2			2	
Homalia trichomanoides	*1*																					2									
Homalothecium sericeum	*20*	3	1	2			3	2	3	3	3		2							2	2	4	2	4	2	2	2		3	3	3
Hypnum cupressiforme	*29*	4	3	3	5	4	5	4	5	5	4	5	4	4	4	4	3	5	4	4	5	4	5		4	5	4	4	4	4	4
Hypnum jutlandicum	*5*	3				2		3																	3						4
Isothecium alopecuroides	*9*	2		1			2				2												2	2			2		2	2	
Isothecium myosuroides	*22*	3	3	3		3	4	3	2	3	2	4	3	2				3		3	4		4	3		3	3	3	4	3	
Leucobryum glaucum	*12*	3	3			2		3	3	3		3		2		3	3	3		2											
Mnium hornum	*24*		4	4	3	3	4		3	3	4	3	3		2			3	3	4	3	3	2	4	3	4	3		3	3	3
Mnium stellare	*9*			3			4		2	1	1											2	3		2					2	
Neckera complanata	*13*	3		1			2		2	2	3	2											3	2			1		3	2	2
Orthotrichum anomalum	*1*																														2
Orthotrichum diaphanum	*1*																													2	
Paraleucobryum longifolium	*8*		2					2		2	2	1	2		2	1															
Plagiomnium affine	*3*											2	2									3									
Plagiomnium cuspidatum	*2*						3																2								
Plagiomnium undulatum	*1*																								2						
Plagiothecium denticulatum	*3*										3		2											3							
Plagiothecium laetum	*10*	3	3	3												2					2		2			3		2		4	2
Plagiothecium nemorale	*4*			2						2	2											2									
Plagiothecium succulentum	*14*	4	4	3		4	3				3	3	3	2									2	3	3				2	4	
Pleurozium schreberi	*7*		1					2	3		2									2	2				2						
Pohlia nutans	*16*	2	3		2	3					2	2		3	3	2				2		2	2	2			2	2			2
Polytrichum formosum	*17*	3	3	4		3		3	2		2	3		3	3	2	2		2	3				2	2						3
Polytrichum juniperinum	*1*		1																												
Pseudotaxiphyllum elegans	*18*	3	3	3	3		3		3	2		3	3	2	2			2	2	2					3	2		3	2		

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Racomitrium heterostichum	*1*														2																
Rhabdoweisia fugax	*5*		3	3			2				2	2																			
Rhizomnium punctatum	*9*		3		2	2	2				2		2											1	2						2
Rhynchostegiella tenella	*17*	3					3	3	2	3	2	2		2	2	2							3	3		2	2	2	2	2	
Rhynchostegium confertum	*3*						2													2											2
Rhynchostegium murale	*3*																					2			3						3
Rhytidiadelphus squarrosus	*1*		2																												
Schistidium apocarpum s.lat.	*1*																														3
Schistidium crassipilum	*1*																											2			
Scleropodium purum	*1*		2																												
Seligeria recurvata	*1*																								1						
Taxiphyllum wissgrillii	*5*			2									2	2			2												2		
Tetraphis pellucida	*23*	3	4	3		3		4	2	3	4	3		3	2	2		3	3	3	3	3	2	3		2	2	3		2	
Tetrodontium brownianum	*1*		1																												
Thamnobryum alopecurum	*4*			2							2			1															2	
Tortula muralis	*10*							2							2							2	2	2	2	2			2	2	2
Weissia controversa	*1*	2																													
Fern																															
Trichomanes speciosum	*6*	2		2			2											1	2				2								
Lichens																															
Absconditella delutula	*3*					v					v									v										
Acrocordia sp.	*7*			v					v	v	v			v		v													v	
Agonimia cf *tristicula*	*2*								v	v																					
Agonimia sp.	*1*			v																											
Arthonia endlicheri	*3*						v	v	v																						
Bacidia rubella	*1*																													v	
Baeomyces rufus	*10*	o	o					v			o	v	o		v		v		o								v				
Biatora chrysantha	*3*	v									v							v													
Bilimbia sabuletorum	*3*																					v			v						v
Botryolepraria lesdainii	*23*	v	v	v	o		o	o	v	v	v	v		v		o			o		v	v	v	v	v	o	v	v	v	v	
Caloplaca chrysodeta	*7*	v		v			v				v											v	v					v			
Caloplaca citrina	*9*	v	o	o					v			o				o				v		v					v				
Caloplaca flavocitrina	*1*																												v		
Caloplaca flavovirescens	*1*																													v	

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Caloplaca ruderum	*3*																						v	v	v						
Candelariella vitellina	*1*																													v	
Chaenotheca furfuracea	*1*		o																												
Cladonia coniocraea	*8*	v	v							v		v			v	v	v							v						
Cladonia digitata	*5*		v							v					v		v	v												
Cladonia fimbriata	*8*	o	o							v					v		v		o	o										o	
Cladonia furcata	*2*																	v							v						
Cladonia macilenta subsp. *floerkeana*	*1*																	v													
Cladonia polydactyla	*3*		v												v			v													
Cladonia portentosa	*1*											v																			
Cladonia ramulosa	*1*											v																			
Cladonia squamosa	*2*		v									v																			
Cladonia sp. (sterile)	*15*	v			v	v		v		v	o	v							v	v			v	v		v	v	v	v		
Cladonia subulata	*1*																v														
Clauzadea monticola	*1*																													v	
Cresponea premnea	*7*					v					v	o		o					v	o										o	
Cystocoleus ebeneus	*3*					v						v								o											
Dimerella pineti	*1*											v																			
Diploicia canescens	*7*							v	o	v		o								o				v						o	
Endocarpon latzelianum	*3*																					v	v		v						
Enterographa sp.	*1*					v																									
Evernia prunastri	*1*																													o	
Hypocenomyce scalaris	*2*													v	o																
Lecania cuprea	*2*	v							v																						
Lecania sylvestris	*3*																			v				v						v	
Lecanora albescens	*1*																							v							
Lecanora campestris	*5*	v		o				v	v	v																					
Lecanora dispersa s.lat.	*13*	v							v		v			v	o	o				v		v	v		v	v		v		v	
Lecanora aff. *horiza*	*9*		o								o		o			o				v									v	v	o
Lecanora orosthea	*4*									v	v			v																v	
Lecidella scabra	*4*								v																v				v	v	
Lepraria crassissima	*13*							v	v	v		v		v	v		v	v	v		v				v	v	v				
Lepraria incana	*22*		v			v		v	v	v	v	v	v	v	v	v	v	v		v	v			v	v	v	v	v	v	v	
Lepraria lobificans	*23*	v	v	v	v	v	v	o		v	v	v	v					v	v	v	v	v	v	v		v	v		v	v	v

Number of location	n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Lepraria obtusatica	*2*		v									v																			
Leptogium teretiusculum	*2*									v													v								
Melanelia glabratula	*3*	o																		v										v	
Micarea bauschiana	*1*																										v				
Micarea botryoides	*5*		v			v						v	v	v																	
Micarea lignaria	*6*	v						v		v		v			v			v													
Micarea myriocarpa	*1*											v																			
Micarea prasina	*6*							v												v	v		v	v						v	
Micarea sp.	*1*																	v													
Opegrapha calcarea	*1*																								v						
Opegrapha mougeotii	*14*	v					o	o	v	v	o	v			o	v				v	o			v	v	v					
Opegrapha cf. *vermicellifera*	*3*					v					o										v										
Opegrapha zonata	*12*	o	o	o							o	v	o	o		o	o	o	o	v											
Parmelia saxatilis	*1*																													o	
Peltigera praetextata	*1*																														o
Physcia adscendens	*1*																													o	
Physconia perisidiosa	*1*																													v	
Physconia sp.	*1*																													o	
Placynthiella icmalea	*3*									v				o	o																
Porina chlorotica s.lat.	*6*					v					v		v						v	v										v	
Protoblastenia rupestris	*1*																													v	
Psilolechia lucida	*14*	o				o		o	v		v			o	o			v	v	o	o		v	v					v		
Rinodina gennarii	*1*																													v	
Sarcogyne regularis	*1*																													v	
Schismatomma sp. (sterile)	*1*											v																			
Trapeliopsis granulosa	*1*																											v			
Verrucaria aff. *calciseda*	*4*																					v	v						v		v
Verrucaria aff. *dolosa*	*8*		v	v							v	v											v		v	v			v		
Xanthoparmelia sp.	*1*																													o	
Total number of hepatic species		7	19	6	2	6	4	3	3	2	7	7	6	3	3	0	4	9	2	2	0	3	3	5	3	2	1	1	1	4	1
Total number of moss species		28	38	23	6	24	25	18	24	24	27	28	18	18	15	13	9	11	11	23	13	20	24	28	30	14	14	14	22	28	31
Combined total bryophyte species		35	57	29	8	30	29	21	27	26	34	35	24	21	18	13	13	20	13	25	13	23	27	33	33	16	15	15	23	32	32
Total number of lichen species		17	16	9	3	11	5	13	14	17	19	23	7	12	13	9	8	12	10	18	8	8	12	12	12	8	9	6	10	28	5
Total number of cryptogam species		53	73	39	11	41	35	34	41	43	53	58	31	33	31	22	21	33	24	43	21	31	40	45	45	24	24	21	33	60	37

Lichens

Absconditella delutula (Nyl.) Coppins & H.Kilias – On rock and humus over rock in contact zone with forest humus; representative specimen: Wolfstal, 1.7 km ESE of Reinhausen, Spribille 18107.
Previously known from Lower Saxony only from around Hamburg (HAUCK 1996) but likely overlooked.

Acrocordia sp. – Frequent on dry vertical rock walls; representative specimen: Wolfstal, 1.7 km ESE of Reinhausen, Spribille 18147.
Characterized by small perithecia 0.2–0.3 mm diam., an open involucrellum and small ascospores 10–15 × 6–8 µm. The specimens are somewhat similar to *A. cavata* (Ach.) R.C. Harris, a rare species which to our knowledge has never been reported from a substrate other than angiosperm bark. PURVIS (1992) describes *A. cavata* as having a hemispherical involucrellum, while POELT & VĚZDA (1977) describe the involucrellum as open below. It is in fact likely that our species is closer to *A. subglobosa* (Vězda) Vězda & Poelt, a poorly known species described from the Czech Republic (B. J. Coppins, pers. comm.). Further work is in progress.

Agonimia cf. ***tristicula*** (Nyl.) Zahlbr. – Wendebachtal, Spribille 17978 (det. P. Diederich).
Numerous thalli in a small discontinuous patch over one square metre. No ascomata were observed, making the identification certain only at the genus level. This is the first record of an *Agonimia* for Lower Saxony.

Arthonia endlicheri (Garov.) Oksner – Uncommon on vertical faces and underhangs; representative specimen: near Reinhausen, Spribille 17993. TLC (3 specimens): lecanoric acid only (major).
New for Lower Saxony and northern Germany; a previous record from adjacent Nordrhein-Westfalen (LAHM 1885, as *A. lobata* [Flot.] A.Massal.) was based on a misidentification of *Dirina stenhammari* (Stenh.) Poelt & Follmann (HAUCK 1996, p. 169). *Arthonia endlicheri* was only recently rediscovered in Germany after being listed as extinct on the last national red list (BUNGARTZ 2000). It superficially resembles a small, weakly lobate, closely adnate thallus of *Lepraria crassissima* or *L. lobificans*. On sterile specimens, the subtle radial structure of the thallus, sometimes ± delimited soralia and presence of lecanoric acid (thallus C+ deep red) are diagnostic. It can be distinguished from *Dirina stenhammari* by the absence of erythrin (TLC).

Aspicilia moenium (Vain.) G.Thor. & Timdal – On rocks within town of Reinhausen, Spribille 17941-C.
New for Lower Saxony. This distinctive sorediate species was not found on any of the natural outcrops included in our survey, but instead on a rain-exposed sandstone face along a busy street in the village of Reinhausen.

Bacidia rubella (Hoffm.) A.Massal. – Rare, found on once: 1 km NNE of Mariaspring near Eddigehausen, Spribille 18184.
Reported as extirpated from Lower Saxony by HAUCK (1996), but recently reported as an epiphyte by BOCH & SPARRIUS (2006).

Botryolepraria lesdainii (Hue) Canals et al. – Common in deeply shaded recesses and caves on the outcrops; representative specimen: Helletal, 0.7 km NNE of Benniehausen, Spribille 17937. TLC (23 specimens): lesdainin only (major).
Known in central Europe from the Czech Republic (BAYEROVA & KUKWA 2004), Austria (HAFELLNER & TÜRK 2001) and Poland (KUKWA 2000), and in Germany from Baden-Württemberg (WIRTH 1995), Lower Saxony (SCHOLZ 2000, without voucher; not recorded by HAUCK 1996!), Rheinland-Pfalz and Nordrhein-Westfalen (SCHOLZ 2000), but widely overlooked. This is the first vouchered report for Lower Saxony.

Cresponea premnea (Ach.) Egea & Torrente – Occasional on dry vertical walls, often around the openings of honey-combed surfaces; representative specimen: Wendebachtal, Spribille 17994.
Last recorded in Lower Saxony by LAHM (1885) from Bad Bentheim and considered by HAUCK (1996) to be extinct in the Federal state (Bundesland).

Endocarpon latzelianum Servít – On rock ledges; Gartetal E of Klein Lengden, Spribille 17970 (W, confirmed by O. Breuß), 17847, 17903.

Fig. 2: *Endocarpon latzelianum* Servít, habit (Spribille 17903). Scale bar = 1 mm.

New for Germany. A distinct species (Fig. 2) that could only be confused with *Endocarpon psorodeum* (Nyl.) Blomb. & Forss., from which it differs in its light-coloured lower surface, smaller squamules and ascospores 28–36 × 14–20 µm. *E. latzelianum* is apparently a central European endemic otherwise known only from the type locality in Dalmatia (SERVÍT 1955) and a subsequent report from Austria (HAFELLNER & TÜRK 2001).

Lecania cuprea (A.Massal.) P.Boom & Coppins – On sheltered vertical wall; Wendebachtal, Spribille 17991.
First record for Lower Saxony since 1909 (HAUCK 1996).

Lecania sylvestris (Arnold) Arnold – On vertical rock face with *Opegrapha mougeotii*; representative specimen: Helletal, 0.7 km NNE of Benniehausen, Spribille 17928.
First record for Lower Saxony since the report by LAHM (1885).

Lecanora aff. ***horiza*** (Ach.) Linds.– On open outcrops, infrequent. Representative specimen: Leuchtetal, 1 km W of Bremke, Spribille 18054. TLC: atranorin only.
Recently reported as an epiphyte from Lower Saxony by BOCH & SPARRIUS (2006), otherwise last report from Lower Saxony from 1912 (HAUCK 1996). Our material is unusual in lacking crystals in the amphithecium when examined in polarized light; it requires further study.

Lepraria crassissima (Hue) Lettau – Frequent on sandstone cliff faces. Representative specimen: Treppenberg, 0.5 km SW of Waldschlösschen, Spribille 18022. TLC (9 specimens): divaricatic acid (major), nordivaricatic acid (submajor), ±zeorin (trace).
First report for Lower Saxony. The species is considered by some authors (e.g., HAUCK 1996, SCHOLZ 2000) to be a synonym of *L. incana*, but it differs from that species in possessing a thick, cottony, hyphal wadding, smaller soredia and higher concentrations of nordivaricatic acid, giving a C+ fleeting pink reaction (TØNSBERG 1992). Our specimens moreover strongly contrasted with *L. incana* on the TLC plates in the absence or near absence of zeorin, which was by contrast nearly always a major constituent in *L. incana*.

Lepraria obtusatica Tønsberg – Discovered during the present survey as new to Germany. The chemistry and distribution of this species are discussed in greater detail by SPRIBILLE & TØNSBERG (2007).

Leptogium teretiusculum (Wallr.) Arnold – Near Reinhausen, on rock; Spribille 17955.
Last record for Lower Saxony was from 1955 (HAUCK 1996), it was considered extirpated on the last Red List (HAUCK 1992). The species was found at two sites. The site where *L. teretiusculum* is most abundant is one of the most popular rock faces for climbing in the Göttingen region, where it is restricted to a few rock ledges in marked climbing routes. Conservation efforts here should be improved.

Micarea bauschiana (Körb.) V.Wirth & Vězda – On rock ledge; Hacketal, 1.6 km E of Waake, Spribille 17868.
Recently reported as new for Lower Saxony by HAUCK (1994) and previously known only from the Harz Mountains (HAUCK 1996).

Micarea myriocarpa V.Wirth & Vězda *ex* Coppins – On underhangs in deep shade, around holes in the rock; Treppenberg, Spribille 18004 (ver. by B. Coppins).
New for Lower Saxony, known in Germany otherwise only from Baden-Württemberg (COPPINS 1983 and the recent collection reported by PALICE 1999).

Micarea sp. – On underhang; Leuchtetal, Spribille 18086.
This rather small specimen appears to belong to a member of the *Micarea prasina* group sensu lato, and is remarkable for its tomentose pycnidia (B. Coppins, pers. comm.). More material is needed.

Muellerella pygmaea (Körb.) D.Hawksw. – On *Lecanora* aff. *horiza* on vertical wall; 1 km NNE of Mariaspring near Eddigehausen, Spribille 18174.
A lichenicolous fungus only sporadically reported from Lower Saxony (HAUCK 1996).

Opegrapha calcarea Turner ex Sm. & Sowerby – On vertical rock face; Helletal, Spribille 17916.
Found only once in a historical quarry. First recent record from Lower Saxony; last reports are from the early 20th century (HAUCK 1996).

Opegrapha mougeotii A.Massal. – On vertical rock faces, common; representative specimen: 1 km N of Ischenrode, Spribille 18207.
O. mougeotii is the most common of three *Opegrapha* species on the Göttingen sandstone formation. It is similar to *Opegrapha varia*, but differs by its pointed lirellae, often 7-septate ascospores, and inconspicuous, immersed thallus. Figures for ascospore sizes differ somewhat in the literature; TORRENTE & EGEA (1989) give ascospore width as 4–5(–6) µm, while PENTECOST & JAMES (1992) state that ascospores are 5–8(–10) µm wide. Our material conforms to the latter dimensions, with most ascospores 21–32 × 5.5–9.0(–10) µm. The specimen of *Opegrapha lithyrga* cited by LAHM (1885) should be reexamined to see whether it conforms to this taxon. *O. mougeotii* has been reported for Lower Saxony but was long treated as a synonym of *O. varia* (e.g., HAUCK 1996).

Opegrapha cf. ***vermicellifera*** (Kunze) Laundon – On vertical faces; Bürgertal, 1.1 km S of Reinhausen, Spribille 18037; Leuchtetal, Spribille 18071.
The specimens are pycnidiate only. A primarily epiphytic species known from a few recent records in Lower Saxony (HAUCK 1996).

Physconia perisidiosa (Erichs.) Moberg – On ledge in shade; 1 km NNE of Mariaspring near Eddigehausen, Spribille 18185.
The population consisted of few individuals that were in poor condition and grazed by snails. Known from only one other site in Lower Saxony (HAUCK 1996).

Verrucaria aff. ***dolosa*** Hepp – Frequent on vertical walls. Representative specimen: Kuhberg, 0.3 km N of Eichenkrug, Spribille 17889.
New to Lower Saxony. Characterized by its continuous to cracked-areolate, greenish thallus, perithecia c. 0.2 mm diam. immersed less than ½ of their height, and ascospores 13.5–18 × 6.0–8.5 µm (in our material). *V. caerulea* DC. has ascospores of similar dimensions but a more strongly areolate, distinctly bluish thallus.

Bryophytes

Campylostelium saxicola (F.Weber & D.Mohr) Bruch & Schimp. – In small patches on a boulder; near Benniehausen, Thiel s.n.
The last records from the Göttingen area are from the 19th century (QUELLE 1902).

Conocephalum salebrosum Szweykowski et al. – Near Reinhausen, Thiel s.n.
In a recent taxonomic revision, two species were recognized within the widespread and common *Conocephalum conicum*, namely *C. conicum* s.str. and *C. salebrosum* (SZWEYKOWSKI et al. 2005). A specimen collected at one of the three surveyed outcrops where *Conocephalum* occurred was identified as *C. salebrosum*. This is the first confirmed record for Lower Saxony, as the report from the Harz mountains by SZWEYKOWSKI et al. (l.c.) might as well originate from adjacent states.

Conardia compacta (Müll.Hall.) H.Robinson – Near Bremke, Thiel s.n.
Occurring in an extensive mat under a slight overhang in direct exposure to climbing. Not mentioned by QUELLE (1902) and GLÄSER (1994), but recently also found in other sandstone localities in the region.

Dicranum spurium Hedw. – Near Benniehausen, Thiel s.n.
A small number of plants were found in *Hypnum* mats on the top of a former quarry. The last records of the species from the Göttingen area date back to the 19th century (QUELLE 1902). The species has become very rare in Lower Saxony and is threatened with extinction (KOPERSKI 1999).

Harpanthus scutatus (F.Weber & D.Mohr) Spruce – Near Ischenrode, Thiel s.n.
This pioneer species grows on small sandstone boulders. It has long been known from the Göttingen sandstone formation, but has become very rare and is threatened with extinction in Lower Saxony (QUELLE 1902, PHILIPPI 1963, GLÄSER 1994, KOPERSKI 1999).

Jamesoniella autumnalis (DC.) Steph. – Near Bremke, Thiel s.n.
Not mentioned by QUELLE (1902) and GLÄSER (1994), but recently also known from other sandstone localities in the region.

Seligeria recurvata (Hedw.) Bruch & Schimp. – On boulders in a quarry; near Benniehausen, Thiel s.n.
Last reports from the Göttingen region were from QUELLE (1902).

Tetrodontium brownianum (Dicks.) Schwägr. – On the 'ceilings' of two small, overhanging ledges; near Ischenrode, Thiel s.n.
Sterile and thus extremely inconspicuous. Originally discovered by M. Preußing (pers. comm.) at a nearby locality in 2002, after it had not been found in Lower Saxony for more than 100 years (QUELLE 1902).

Discussion

Effects of rock climbing on cryptogam vegetation

There have been numerous studies on the effects of sport rock climbing on both cryptogams and vascular plants (SCHÖLLER 1994, FARRIS 1998, MÜLLER et al. 2004, KUNTZ & LARSON 2006). Several authors have pointed to absence or reduced presence of species on rock climbing sites as evidence of negative effects. In a study of both cryptogams and vascular plants in Minnesota, FARRIS (1998) found reduced cover and frequency of most taxa on climbed cliffs compared with unclimbed areas. He investigated three cliff systems on Sioux quartzite sandstone, basalt and rhyolite, respectively, each in much different climatic situations. Perhaps not surprisingly, he found different species on every cliff system, but a more or less consistent pattern of lower cover of bryophytes and foliose and umbilicate lichens on climbed cliffs and lower numbers of species in several cases. Working on limestone in the Swiss Jura, MÜLLER et al. (2004) found reduced cover and lower densities of vascular plants per square metre and lower frequency of rock outcrop specialists on climbed versus unclimbed rock faces. However, even as FARRIS (1998) already noted, such observations must be interpreted with caution as it is not clear that human use is causal of vegetation patterns, being that climbers prefer cliffs that are free of interfering vegetation. This was recently demonstrated by KUNTZ & LARSON (2006), who controlled for microtopography between climbed and unclimbed cliffs in southern Ontario and found that microtopography, not climbing activity, explained most differences in vegetation and that sport climbers tend to choose cliffs with less vegetation in the first place.

Our study was strictly an inventory; it was not designed to answer the question of whether climbing has an effect on cryptogam vegetation. There are furthermore several reasons why this would have been difficult, if not impossible, to demonstrate directly. First, almost all of the outcrops we studied are used for climbing, and indeed all cliffs suitable for climbing are used for that purpose; there are no suitable control sites. Second, we did not assess cryptogam vegetation on a microplot level relative to climbed versus unclimbed routes, and even if we had, there is no guarantee that unclimbed routes would serve as a suitable control for climbed

routes owing to the same microtopographic differences found by KUNTZ & LARSON (2006). It is possible that, as in the American studies, cover and composition have not been significantly impacted, i.e., that overall vegetation on climbed and unclimbed cliffs of the same microtopographic diversity, exposure and aspect would be broadly similar.

The ecological behavior of a majority of species, however, cannot be equated with the ecological behavior of individual species whose existence may be threatened. There are several 'bellwether' species whose microhabitat requirements, namely dry vertical faces and overhangs, are closely congruent with the most favoured climbing/bouldering sites in the Göttingen region. These include the lichens *Acrocordia* sp., *Agonimia* cf. *tristicula*, *Arthonia endlicheri*, *Endocarpon latzelianum*, *Lecania cuprea*, *Lecania sylvestris*, *Lecanora* aff. *horiza* and *Leptogium teretiusculum*, and the moss *Conardia compacta*, all regionally rare species that are found only in or immediately next to high use climbing areas, and in some cases in the direct vicinity of rock faces that have been 'cleaned' with brushes for optimal climbing. We know nothing about population trends in these species from pre-climbing times to the present, but it is likely that they have been impacted in some way. The occurrence/population trends of these species should be monitored with respect to potential future impacts from rock climbing.

Other factors in cryptogam decline

The rich diversity of the cryptogam flora of the Göttingen sandstone outcrops is set against the background of overall decline in the cryptogam flora. Of the 262 lichen species reported from the vicinity of Göttingen in the last 240 years, about 40 % have not been recorded since 1900 (HAUCK 1995). The role of sulfur dioxide pollution on lichen decline in the course of the industrial revolution is well documented. Unfortunately, we have no baseline on which we can assess what lichens occurred on the studied sandstone outcrops before industrialization or before the onset of rock climbing activities. For bryophytes a comparison of the floras of QUELLE (1902) and GLÄSER (1994) shows a strong decline of calcium-dependent saxicolous species such as *Anomodon attenuatus* and *Neckera crispa* in the sandstone areas, while some species growing on highly acidic substrates, e.g., *Campylopus flexuosus*, have obviously spread. WEIS (1770) reports *Cladonia coccifera* and *Parmelia saxatilis* as 'copious' from rock and moss over rock around Waake, one of the areas included in our study; we found neither species there in our surveys. There is also a report of *Lasallia pustulata* from c. 1835 in the vicinity of Waake (HAUCK 1995), but it too was likely extirpated.

There are additional overarching reasons for the decline of saxicolous lichens on the Göttingen sandstone cliffs. Changes in forestry practises are likely responsible at least in part. Given the open pastoral landscape typical of pre-industrial revolution central Europe, it is probable that the outcrops seen by WEIS in the 18th century were more sun-exposed and better ventilated than at present. In tandem with the shift from traditional forest pastoralism and coppiced *Quercus* woodlands towards industrial forestry, the cultural landscape around Göttingen has morphed into single-cohort, dense *Fagus sylvatica* forests and *Picea abies* plantations (ELLENBERG 1996). In addition to compound negative effects on epiphytic cryptogams, this has meant the increased shading of forest rock outcrops and increased deposition of leaf litter on outcrop 'heads', and has likely contributed to the demise of species such as *Lasallia pustulata* that occur mainly on open, exposed rock. Vertical faces and rain-sheltered underhangs of sandstone outcrops today represent some of the only remaining, natural, base-enriched habitats in a heavily managed, acidified landscape. They are islands of lichen diversity in a severely degraded environment, and deserve closer study.

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