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Lichens in the New Botanical Garden of the University of Zürich, Switzerland

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Abstract

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The lichen flora of the 30 years old New Botanical Garden of the University of Zürich was investigated. In total 149 species of lichen-forming ascomycetes were found, including Red Listed species like *Arthonia dispersa* and *Parmotrema perlatum.* The following species were recorded for the first time in Switzerland: *Bacidia adastra, Flavoparmelia soredians* and *Lecanora xanthostoma*. 18 species of lichenized and 2 species of non-lichenized ascomycetes are new records for the Canton of Zürich. Our data are compared with published inventories of the epiphytic, foliose and fruticose lichens of the city of Zürich from the first and second half of the 20th century. A range of *Peltigera* spp. was transplanted to the most humid and shady part of the alpine garden and their growth and development monitored. Spontaneously growing and introduced lichen species in the relatively small Zürich Botanical Garden amount to almost 10% of all lichen species known from Switzerland.

Key words: Epiphytic lichens, saxicolous lichens, terricolous lichens, *Peltigera* transplants, *Peltigera leucophlebia* photosymbiodeme.

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Introduction

The New Botanical Garden of the University of Zürich was built on the grounds of the former Schönau park at the periphery of the city on the SW-facing moraine hill bordering upon lake Zürich at approximately 420 m altitude. At the site of the former villa Schönau, an elegant mansion built in 1866, the new institute buildings were constructed, comprising the institutes of Systematic Botany and Plant Biology of the University of Zürich. With its 53'000 m^2 the garden is relatively small, but it has an interesting topography and harbours a rich diversity of plants. At the sunny, SW-facing hillside, formerly a vineyard and now well protected from Northern winds by the institute buildings, the Mediterranean garden is situated with an adjacent wadi (arabian word for a dry riverbed). In the small valley to the Northeast the semiglobose greenhouses, a pond, a rich collection of water plants, the economic plant sector and, in the shade of the institute buildings, the alpine garden (Alpinum) are located. Many of the newly planted trees have reached impressive sizes, but numerous beautiful old trees from the former Schönau park, solitary or in groups, add special beauty to the assembly. Construction work was completed in fall 1976. The garden was officially opened in spring 1977.

This study is an inventory of the lichen species found in the New Botanical Garden of the University of Zürich after the first thirty years of its existence. It was interesting to observe the colonization of natural rock surfaces and anthropogenic substrata by lichens and to monitor growth rates and even successions of species. The majority of species appeared spontaneously, but few were transplanted to the garden. Their growth and development in the new environment is briefly summarised.

Materials and Methods

All habitats of the Botanical Garden were systematically checked in a 3 days collecting trip. The following floras were mainly used for identification: Purvis et al. (1992), Wirth (1995) and van Herk and Aptroot (2004). Thin layer chromatography (TLC) was used to verify some sterile crusts. Voucher specimens are deposited in the herbaria of the university and ETH Zürich (Z+ZT).

Peltigera *transplants in the New Botanical Garden of the University of Zürich*

In 1994 several *Peltigera* species were transplanted for research and teaching purposes to the most humid and shady, NE-facing hillside of the alpine garden. Shaded by the institute building and, from spring to fall, by a group of large deciduous trees, remains from the former Schönau park, this area is insolated during few hours only in the morning. Thallus fragments were pinned to the moss carpet covering limestone blocks by means of fragments of the robust, dry needles of *Pinus nigra*. In successful transplants old and newly formed rhizinae fixed the lichen fragments to the substratum within few weeks. The pine needles started to rot after few months. Transplants were photographed in irregular intervals, with and without superimposed reference grid. Morphometric methods are described in Honegger et al. (1996).

Results and Discussion

Spontaneously growing lichen species

Table 1 shows a list of all lichen species recorded on different types of substrates in the Botanical Garden in August 2005. A total of 149 species was recorded, including three species new for Switzerland, which equals approximately 10% of all lichen species known to occur in Switzerland (Clerc 2004). 18 species of lichen-forming and 2 species of non-lichenized ascomycetes are new records for the Canton of Zürich. During a short visit in summer 1999 to part of the garden, already 88 species of lichen-forming fungi were found (Aptroot et al. 2001). All of them were still present in 2005, and 61 additional species were recorded. Only lichen-forming ascomycetes were found, whereas representatives of the few lichenized basidiomycetes are so far missing. However, fruiting bodies (basidiomata) of non-lichenized *Omphalina* species were repeatedly found in the shady part of the alpine garden and between the pavement of the amphitheatre (R. Honegger and J. Schneller, pers. observ.). Most taxa are symbiotic with green algal partners, *Trebouxia* spp. being the most common photobionts. The majority of species form crustose thalli, some of them being rather inconspicuous (coloured photographs in Wirth 1995; van Herk and Aptroot 2004). Morphologies and substrate preferences of the lichens from the New Botanical Garden of the University of Zürich are summarised in Figure 1.

Saxicolous lichen species

Saxicolous lichens find a rich diversity of natural and anthropogenic rock substrates which, upon completion of the landscape work in late 1976, were all pristine. Limestone blocks from central Switzerland (Lopper), granite from Southern Switzerland (Maggiatal), and Verrucano (a permian breccia rich in silicates, originating from the Canton of Glarus) were used for shaping the alpine garden. Numerous larger and

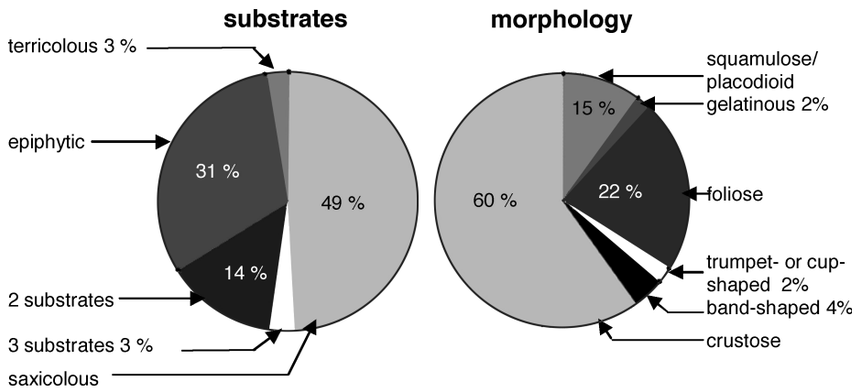


Fig. 1. Substrate preference and morphology of the lichens in the New Botanical Garden of the University of Zürich. Lignicolous lichens do not show up as a separate group since all species were also growing on other substrates; thus they are included in sectors "2 substrates" and "3 substrates".

Tab. 1. Lichens of the New Botanical Garden of the University of Zürich in August 2005
Red list status: **EN**: endangered; **VU**: vulnerable; **NT**: near threatened. **CH** and bold: first report for Switzerland; **ZH**: first report for Canton of Zürich. Substrates: **e**: epiphytic; **s**: saxicolous; **t:** terricolous; **w**: on wood. Not listed: introduced species

	Acarospora fuscata (Schrad.) Th. Fr.	s
	Acarospora smaragdula (Wahlenb.) A. Massal.	s
	Acarospora umbilicata Bagl.	s
	Agonimia globulifera A.M. Brand & Diederich	t
	Amandinea punctata (Hoffm.) Ch. Scheideg.	e
ZH	*Anisomeridium polypori* (Ellis & Everh.) M.E. Barr	e
EN	*Arthonia dispersa* (Schrad.) Nyl.	e
	Aspicilia caesiocinerea (Nyl. ex Malbr.) Arnold	s
	Aspicilia calcarea (L.) Körb.	s
	Aspicilia contorta s.s. (Hoffm.) Kremp.	s
	Aspicilia contorta ssp. hoffmaniana Ekman & Fröberg	s
ZH	*Aspicilia moenium* (Vain.) G. Thor & Timdal	s
	Aspicilia radiosa (Hoffm.) Poelt & Leuckert	s
CH	***Bacidia adastra*** Sparrius & Aptroot	e,s
	Bacidia neosquamulosa Aptroot & van Herk	e
	Bacidia subincompta (Nyl.) Arnold *nom. cons. prop.*	e
	Bacidia viridifarinosa Coppins & P. James	s
	Bacidina arnoldiana (Körb.) V. Wirth & Vězda	e
ZH	*Bacidina caligans* (Nyl.) P. Clerc	e, s, t
	Bacidina delicata (Leight.) V. Wirth & Vězda	s
	Bacidina inundata (Fr.) Vězda	s
	Bilimbia sabuletorum (Schreb.) Arnold	s
	Buellia aethalea (Ach.) Th. Fr.	s
	Buellia badia (Fr.) A. Massal.	s
	Buellia griseovirens (Turner *ex* Borrer *ex* Sm.) Almborn	e, w
	Caloplaca chlorina (Flot.) H. Olivier	s
	Caloplaca citrina (Hoffm.) Th. Fr.	s
ZH	*Caloplaca coronata* (Körb.) J. Steiner	s
ZH	*Caloplaca crenulatella* (Nyl.) H. Olivier	s
ZH	*Caloplaca dalmatica* (A. Massal.) H. Olivier	s
	Caloplaca flavocitrina (Nyl.) H. Olivier	s, w
	Lecania erysibe (Ach.) Mudd	e, s
	Lecania rabenhorstii (Hepp) Arnold	s
	Lecanora barkmaniana Aptroot & van Herk	e
	Lecanora campestris (Schaerer) Hue	s
	Lecanora carpinea (L.) Vainio	e
	Lecanora chlarotera Nyl.	e, w
	Lecanora conizaeoides Nyl. *ex* Crombie	e
	Lecanora dispersa (L.) Sommerf.	s
	Lecanora expallens Ach.	e
ZH	*Lecanora flotowiana* Sprengel	s
	Lecanora hagenii (Ach.) Ach.	s
	Lecanora muralis (Schreber) Rabenh.	s
ZH	*Lecanora persimilis* (Th. Fr.) Nyl.	e
	Lecanora polytropa (Hoffm.) Rabenh.	s
	Lecanora pulicaris (Pers.) Ach.	e, w
	Lecanora saligna (Schrad.) Zahlbr.	e

Tab. 1 *(continued)*

CH	***Lecanora xanthostoma*** Cl. Roux *ex* Fröberg	s
	Lecidea fuscoatra (L.) Ach.	s
ZH	*Lecidea lithophila* (Ach.) Ach.	s
	Lecidea variegatula Nyl.	s
	Lecidella carpathica Körb.	s
	Lecidella elaeochroma (Ach.) M. Choisy	e, w
	Lecidella flavosorediata (Vězda) Hertel & Leuckert	e
	Lecidella scabra (Taylor) Hertel & Leuckert	s
ZH	*Lecidella stigmatea* (Ach.) Hertel & Leuckert	s
	Lepraria incana (L.) Ach.	s
	Lepraria lobificans Nyl.	e, s
ZH	*Lepraria rigidula* (de Lesd.) Tønsberg	e
	Lepraria vouauxii (Hue) R.C. Harris	s
NT	*Melanelia elegantula* (Zahlbr.) Essl.	e
	Melanelia exasperatula (Nyl.) Essl.	e
	Melanelia fuliginosa (Fr. *ex* Duby) Essl.	e, s
	Melanelia subaurifera (Nyl.) Essl.	e
	Neofuscelia pulla (Ach.) Essl.	s
	Normandina pulchella (Borrer) Nyl.	s
NT	*Ochrolechia turneri* (Sm.) Hasselrot	e
	Toninia aromatica (Sm.) A. Massal.	s
	Trapelia coarctata (Sm.) M. Choisy	s
	Trapelia involuta (Taylor) Hertel	s
	Usnea subfloridana Stirt.	e
	Verrucaria dolosa Hepp	s
	Verrucaria macrostoma DC.	s
	Verrucaria muralis Ach.	s
	Verrucaria nigrescens Pers.	s
	Caloplaca flavovirescens (Wulfen) dalla Torre & Sarnth.	s
	Caloplaca holocarpa (Hoffm.) A.E. Wade	s
	Caloplaca lactea (A. Massal.) Zahlbr.	s
	Caloplaca lithophila H. Magn.	s
ZH	*Caloplaca oxfordensis* J. Hetrick	s
	Caloplaca pyracea (Ach.) Th. Fr.	e
	Candelaria concolor (Dicks.) Stein	e, s
	Candelariella aurella (Hoffm.) Zahlbr.	s
	Candelariella reflexa (Nyl.) Lettau	e, s, w
	Candelariella vitellina (Hoffm.) Müll. Arg.	s, w
	Catillaria chalybeia (Borrer) A. Massal.	s
	Cladonia fimbriata (L.) Fr.	s, t
	Cladonia macilenta Hoffm.	e
ZH	*Cladonia pocillum* (Ach.) Grognot	s, t
	Collema crispum (Huds.) F.H. Wigg	s, t
	Collema limosum (Ach.) Ach.	t
	Collema tenax (Swartz) Ach.	t
	Dimerella pineti (Ach.) Vězda	e
	Diploschistes muscorum (Scop.) R. Sant.	t
	Endocarpon pusillum Hedw.	e, t
ZH	*Evernia divaricata* (L.) Ach.	e
	Evernia prunastri (L.) Ach.	e

Tab. 1 *(continued)*

	Flavoparmelia caperata (L.) Hale	e, w
CH	***Flavoparmelia soredians*** (Nyl.) Hale	e
	Gyalideopsis anastomosans P. James & Vězda	e
	Halecania viridescens Coppins & P. James	e
	Hyperphyscia adglutinata (Flörke) H. Mayerhofer & Poelt	e, s
	Hypogymnia physodes (L.) Nyl.	e
	Hypogymnia tubulosa (Schaerer) Hav.	e
	Hypotrachyna revoluta (Flörke) Hale	e
	Lecania cyrtella (Ach.) Th. Fr.	e
	Parmelia saxatilis (L.) Ach.	e
	Parmelia sulcata Taylor	e, w
	Parmelina tiliacea (Hoffm.) Hale	e
VU	*Parmotrema perlatum* (Eschw.) M. Choisy	e
	Peltigera didactyla (With.) J.R. Laundon	s
	Phaeophyscia chloantha (Ach.) Moberg	s
	Phaeophyscia nigricans (Flörke) Moberg	s
	Phaeophyscia orbicularis (Neck.) Moberg	e, s
	Phlyctis argena (Spreng.) Flot.	e, s, w
	Physcia adscendens (Fr.) H. Olivier	e, s, w
	Physcia aipolia (Humb.) Fürnr.	e
	Physcia caesia (Hoffm.) Fürnr.	s
	Physcia stellaris (L.) Nyl.	e
	*Physcia tenella (*Scop.) DC.	e, s, w
	Physconia grisea (Lam.) Poelt	e, s
	Placynthium nigrum (Huds.) Gray	s
	Platismatia glauca (L.) W.L. Culb. & C.F. Culb.	e
	Polysporina simplex (Davies) Vězda	s
	Porpidia crustulata ((Ach.) Hertel & Knoph	s
	Porpidia macrocarpa (DC.) Hertel & A.J. Schwab	s
ZH	*Porpidia soredizodes* (Lamy *ex* Nyl.) J.R. Laundon *	s
	Porpidia tuberculosa (Sm.) Hertel & Knoph	s
	Protoblastenia rupestris (Scop.) J. Steiner	s
	Pseudevernia furfuracea (L.) Zopf	e
	Psorotichia schaereri (A. Massal.) Arnold	s
	Punctelia subrudecta (Nyl.) Krog	e
	Punctelia ulophylla (Ach.) van Herk & Aptroot	e, w
	Ramalina farinacea (L.) Ach.	e
NT	*Ramalina pollinaria* (Westr.) Ach.	e
	Rhizocarpon geographicum (L.) DC.	s
	Rhizocarpon reductum Th. Fr.	s
	Sarcogyne clavus (DC.) Kremp.	s
	Sarcogyne regularis Körb.	s
	Sarcosagium campestre (Fr.) Poetsch & Schied.	t
	Scoliciosporum chlorococcum (Stenh.) Vězda	e
	Scoliciosporum umbrinum (Ach.) Arnold	s
ZH	*Verrucaria pinguicula* A. Massal.	s
	Verrucaria steineri Kusan	s
	Verrucaria tectorum (A. Massal.) Körb.	s
ZH	*Verrucaria umbrinula* Nyl.	s
	Xanthoria candelaria (L.) Th. Fr.	e

Tab. 1 *(continued)*

Xanthoria elegans (Link) Th. Fr.	s
Xanthoria parietina (L.) Th. Fr.	e, s
Xanthoria polycarpa (Hoffm.) Rieber	e

* First report for Switzerland by Dietrich (2006) on a medieval wall in Lucerne.

smaller boulders originating from the underlying moraine material are positioned in the Mediterranean garden and adjacent areas of the wadi and at the periphery of the alpine garden. They comprise conglomerates ("Nagelfluh"), granite, sandstone, limestone etc. Pavements are made from porphyr (terrace in front of the cafeteria), granite and sandstone (amphitheatre).

Among the most unexpected species were *Normandina pulchella* and *Phaeophyscia chloantha* (incorrectly reported as *Physcia dubia* in Aptroot et al. 2001), which were all found on granite blocks in the alpine garden. Thalli of *Rhizocarpon geographicum*, now measuring 9–14 mm in diameter, grow on porphyr blocks opposite the cafeteria, on the granite pavement in the amphitheatre and on the porphyr pavement (largest diameter) in the water plant garden. A species-rich lichen community is found on the odd-shaped limestone blocks in the assembly of (potted) *Agave* and *Yucca* spp. to the left of the entrance of the greenhouses: *Verrucaria steineri* (syn. *Bagliettoa steineri)*, *Caloplaca crenulatella* (sensu Wirth 1995)*, C. lactea* (sensu Purvis et al. 1992, characterized by the small apothecia and the absence of yellow pigments in the thallus)*, C. dalmatica, Collema limosum, Placynthium nigrum,* and *Sarcogyne regularis.* Even on the tuff blocks inside the savannah greenhouse was a crustose species detected: *Bacidia delicata*.

Artificial ponds and basins in the water plant sector, the semicircular garden benches, and the outer mantle of garbage bins throughout the garden are made from concrete. *Bacidina inundata*, as found at the basins of the water plant garden, is the first report for Switzerland after Stizenberger (1882–83). Some of the garbage bins reveal a colourful lichen patina, *Caloplaca citrina* being the most conspicuous species. Interestingly, the concrete surfaces support some species which were rarely, if ever, recorded from Switzerland: *Aspicilia moenium* was found to be abundant on the SW-facing concrete wall at the entrance of the greenhouses, while *Caloplaca chlorina, C. flavocitrina, Lecanora flotowiana,* and *L. xanthostoma* (first report from Switzerland) grow on many concrete benches, especially near the North entrance of the garden. The tiles on the beehouse, another anthropogenic substratum situated in the northern part of the garden ("Bienengarten"), carry luxuriant growth of *Candelaria concolor* and *Hyperphyscia adglutinata*, species which are normally corticolous (and are abundantly so as well in the garden).

One of the saxicolous lichen communities was observed to change quite dramatically within relatively short periods of time as part of a natural succession. Growth and development of a population of *Xanthoria parietina* was monitored and quantitatively evaluated over several years on a sandstone block originating from the moraine material at the periphery of the alpine garden (Honegger et al. 1996). In 1989 this block was overgrown by foliose lichens, but already in 1994 the first bryophyte (*Orthotrichum* sp.) established on the plot under survey, and mosses successively outcompeted the lichens within a period of less than three years. Today this block carries no macrolichens at all, but a well developed moss cover.

Epiphytic lichen species

Epiphytic lichens are most abundant on few of the old and on some of the newly planted shrubs and trees. No to very little lichen growth is recorded on the old birches (*Fagus sylvatica,* with stem diameters between 1.5 and 1.9 m), pine (*Pinus nigra*), white fir (*Abies alba*), yew (*Taxus baccata*) or box trees (*Buxus sempervirens*), all of which were part of the former Schönau park. The (by now dying) last survivor of a series of more than 150 years old lime trees (*Tilia platyphyllos*) carries a limited number of lichen species. The rare *Bacidia subincompta* was found on the stem of an old elm (*Ulmus scabra*) at the NE corner of the institute building. Several lichen species were recorded on an old maple (*Acer pseudoplatanus*), but an old oak (*Quercus robur*) in the SE part of the garden underneath the small amphitheatre "Eichenkänzeli" carried the most diverse lichen flora (e.g. *Parmelia saxatilis, Physcia stellaris*, *P. aipolia* among many other species). Among the newly planted trees a young *Sorbus domestica* (sorb-tree), *Quercus petraea, Q. castaneifolia*, *Platycaria strobilacea* and *Euodia hupehensis* (died off after the drought in 2003) are well colonized. The recently described *Bacidia adastra* (here reported for the first time from Switzerland) is common on many trees, e.g. a *Prunus mahaleb* with a nitrophytic flora comprising *Candelaria concolor, Candelariella reflexa* and *Physcia tenella* (with apothecia). *Flavoparmelia soredians* (new to Switzerland) and *Parmotrema perlatum* (Red Listed as vulnerable; Scheidegger and Clerc 2002) were found on newly planted *Q. petraea*, *Bacidia neosquamulosa*, *Gyalideopsis anastomosans*, *Lepraria rigidula* on e.g. *Q. castaneifolia*, *Lecidella flavosorediata* and *Ochrolechia turneri* (Red Listed as near-threatened) on *S. domestica,* all at or near the vantage point "Eichenkänzeli". *Anisomeridium polypori* grows on *Catalpa bignonioides* facing the entrance the newly built research glass houses in the southwestern part of the garden. A more acidic flora, with e.g. *Evernia divaricata, Lecanora conizaeoides, L. saligna, Platismatia glauca* and *Strangospora pinicola,* was recorded on *Acer* and *Ailanthus altissima* (tree of heaven) in front of the Botanical garden at Zollikerstrasse. Very conspicuous and diverse lichen growth occurs on some of the shrubs and small trees belonging to the Hamamelidaceae (*Hamamelis mollis*, *H. intermedia, H. vernalis, Parrotia persica, Parrotiopsis jacquemontiana*) in the NE part of the garden. More than 20 lichen species were found on *H. mollis* (witch hazel*)*, whose hairy epidermis of first years growth is an excellent substratum for symbiotic propagules of numerous lichen-forming ascomycetes (Fig. 2a – a′). *Caloplaca pyracea*, *Halecania viridescens* and *Lecanora carpinea* grow on *Parrotia persica*. The stem of one of the *Hippophaë rhamnoides* shrubs (sea buckthorn) at the periphery of the wadi is fully overgrown by *Cladonia macilenta*. Some of the potted shrubs, which are not frost resistant and therefore brought into a greenhouse for hibernation, carry a rich and diverse, very conspicuous lichen flora. On *Ligustrum japonicum* and *Schinus molle* (mastic or false pepper tree) approximately 20 lichen species were found, Parmeliaceae being most prominent (*Punctelia*, *Flavoparmelia* and *Parmelia* spp.), but also the Red Listed *Ramalina pollinaria* (near-threatened) is present. *Punctelia ulophylla* is dominant, and grows here side-by-side with *P. subrudecta. Arthonia dispersa*, *Lecania cyrtella*, *L. erysibe* and *Lecanora barkmaniana* and the golden yellow *Xanthoria parietina* grow on the old stems of *Brugmansia* spp. (angel's trumpets). These data convincingly show that at a given climate not only pollutants have an impact on epiphytic lichen growth, but mainly phorophyte-specific properties such as the texture and especially the water holding and buffer capacity of the bark. These parameters,

although being described in the literature (e.g. Barkman 1958), are often not considered and discussed in mapping studies for monitoring air pollution.

Three interesting non-lichenized epiphytic ascomycetes were observed: *Naetrocymbe punctiformis* (Pers.) R.C. Harris (formerly *Arthropyrenia punctiformis* (Pers.) A. Massal.), *Leptorhaphis epidermidis* (Ach.) Th. Fr. and *L. maggiana* (A. Massal.) Körb., the latter 2 species being new records for the Canton of Zürich.

In the Botanical Garden epiphytic lichen communities are more prone to changes than saxicolous communities. The first *Usnea* thallus found in this garden was lost when a large branch of *Hamamelis mollis* was cut back. Many trees in the Botanical Garden of the University of Zürich suffer from severe attacks of root rot fungus (*Armillaria mellea* s. lat.), whose rhizomorphs seem to have reached frightening dimensions as trees and shrubs died from root rot in an area spanning from the entrance at Zollikerstrasse to the pond in the valley behind the institute building. Therefore we will probably have to face additional losses in near future. Due to infection by this parasite several ornamental cherry trees, a beautiful allspice shrub (*Chimonanthus praecox*) and a *Metasequoia glyptostroboides* were lost, and our formerly large and beautiful "handkerchief trees" (*Davidia involucra*) are severely injured. From a lichenological point of view the ornamental cherry trees (*Prunus* spp.) were a major loss. They carried, among several *Physcia* species, a very rich population of *Xanthoria polycarpa* on their fine twigs, which were used in an ongoing research project on mating systems in lichen-forming fungi (Scherrer et al. 2005).

Lignicolous lichen species

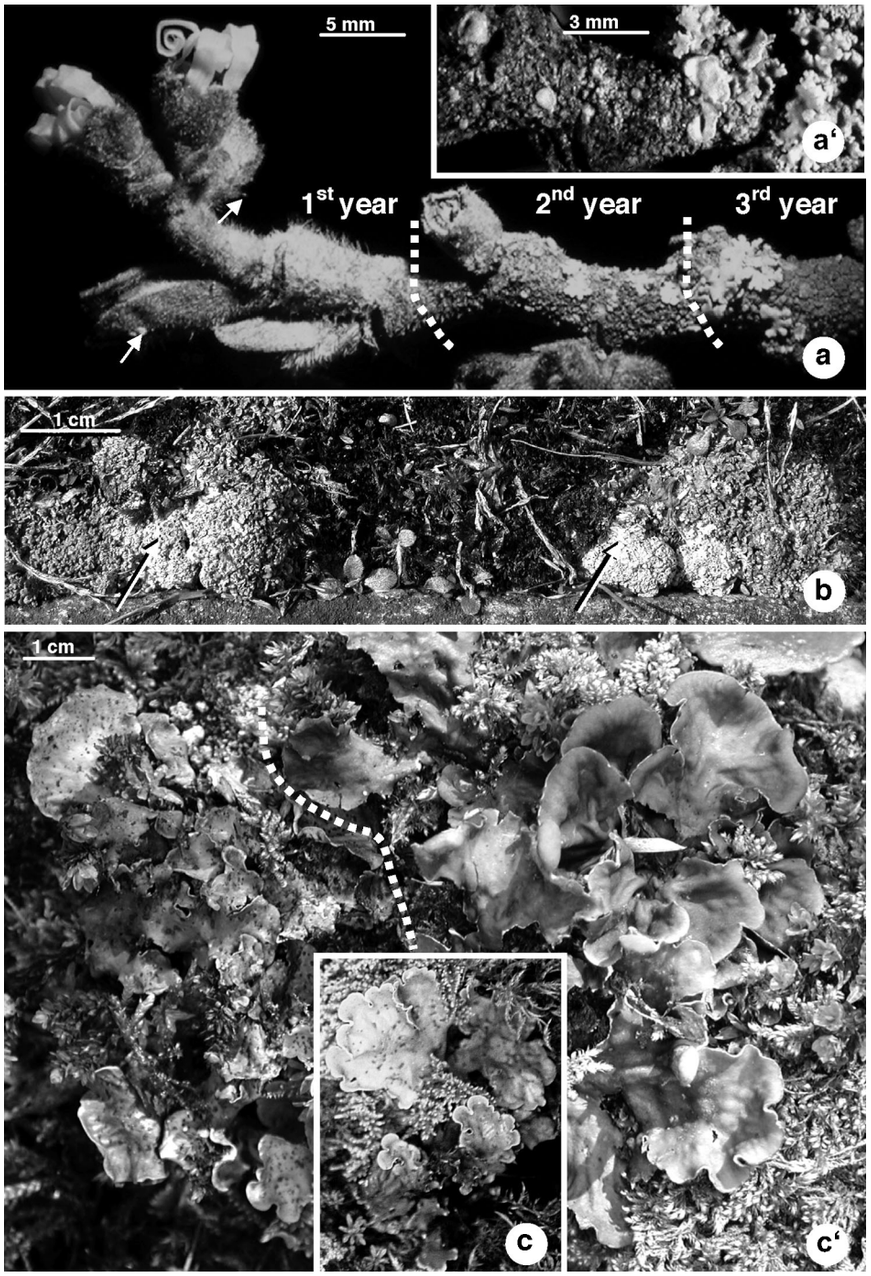
Lignicolous lichens grow mostly on unpainted wooden garden benches, whose surface treatment has washed out in the 30 years of their existence *in situ*. Old wooden pots of the non-frost resistant perennials are another substrate for lignicolous species. All species found on wood occur on more than one substrate: they are either lignicolous and epiphytic (7 spp.) or lignicolous and saxicolous (3 spp.) or grow on all three substrata (3 spp.; Tab. 1); therefore they do not show up as a separate sector in Figure 1.

Terricolous lichen species

Terricolous lichens develop mainly in the interspaces of pavement, the highest diversity being found in the amphitheatre. As this site is very popular among visitors and people of the institute it is subjected to continuous trampling. Therefore *Cladonia pocillum* is rarely seen with podetia, and it will be interesting to follow up the development of the first lobules of *Peltigera didactyla* at this location. Many of the thalli of *Cladonia pocillum* are invaded by the lichenicolous lichen-forming ascomycete *Diploschistes muscorum* (Fig. 2b). The lichen vegetation reminds that of calcareous dune machair, with *Agonimia globulifera* (still only known from this locality in Switzerland), *Endocarpon pusillum* and *Sarcosagium campestre.*

Peltigera *transplants*

Transplanted *Peltigera* species with cyanobacterial photobiont, originating from Swiss collecting sites (Murgtal), grew well in the New Botanical Garden. Already in the first year, successful transplants of *P. rufescens* (Weiss) Humb. (Fig. 3) revealed an almost 500% size increase, as estimated from morphometric measurements. In summer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2nd year
3rd year
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c'

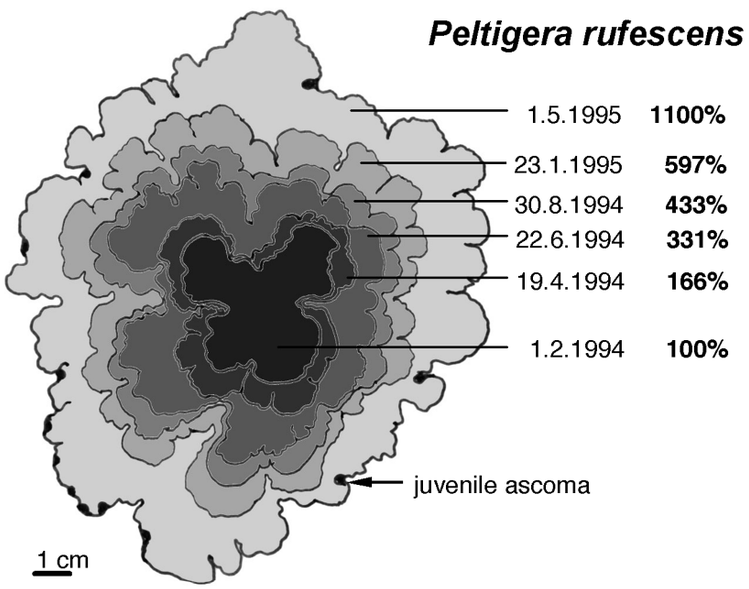

Fig. 3. Outlines of the same thallus transplant of *Peltigera rufescens* after different periods of time.

2005, many of the large boulders in this part of the alpine garden carried luxuriant growth of *P. praetextata* (Sommerf.) Zopf, *P. rufescens.* and *P. malacea* (Ach.) Funk. *Peltigera rufescens* and *P. malacea* are now richly fertile. Few of the transplants were outcompeted by bryophytes. Many large thalli growing on the vertical lateral sides of the boulders detached and fell off when wet. A major problem was caused by blackbirds which, especially in spring, tore mosses and lichens away from the rock surfaces in search of arthropods. Transplants were therefore protected and stabilized with a loosely woven nylon fabric, which was soon overgrown. Many young thalli of *P. rufescens* and *P. praetextata* are now found overgrowing mosses on the rocks of the alpinum. These species are well established and spreading. Transplanted *P. membranacea*, collected in coastal Washington State (USA), could not establish and died off within the first year.

Peltigera spp. with a green alga (*Coccomyxa* sp.) as their main photobiont and a diazotrophic cyanobacterial partner (*Nostoc punctiforme*) in tiny, blackish nodules

Fig. 2. a–a') Epiphytic lichen growth on youngest twigs of *Hamamelis mollis*, with settlement of soredia on the hairy epidermis of first year growth. a') detail of the transition zone between 2nd and 3rd year of twig age. Arrows in a point to thallus primordia derived from soredia. *Physcia adscendens*, *Parmelia sulcata* and *Hypogymnia physodes* are the most common colonizers of young twigs. b) Terrestrial lichen community developing in crevisses between the pavement of the amphitheatre. Arrows point to richly fertile, whitish *Diploschistes muscorum* invading the thalli of *Cladonia pocillum*. c–c') Transplant of *Peltigera leucophlebia* after 1 year (c) and 4 years of transplantation (c'), after having formed a photosymbiodeme. Dashed line marks the border between the green chloromorph and blackish-grey cyanomorph, the latter being distinctly more robust and growing faster than the chloromorph. Same magnification in c and c'.

(cephalodia) on their thallus surface are distinctly less common in nature than the species with cyanobacteria as primary photobiont. Transplants of *P. britannica* (Gyelnik) Holt.-Hartw. & Tønsb. from coastal Washington State (USA) did not survive. Only one out of three transplants of *P. leucophlebia* (Nyl.) Gyeln. from Switzerland survived, the others being outcompeted by bryophytes. On this green photomorph (chloromorph) a photosymbiodeme developed (Fig. 2c–c′), with blackish-grey lobes, formed by presumably the same fungal partner in association with the cyanobacterium as primary and only photobiont (cyanomorph; review: Goffinet and Bayer 1997). The lobes of the green photomorph grew only very slowly and by now are almost completely overgrown by the cyanobacterial photomorph, which is already forming its first fruiting bodies (ascomata). It will be interesting to see whether this is a self-fertile (homothallic) or cross-fertilized (heterothallic) lichen-forming ascomycete. The switch from the green algal to the cyanobacterial photomorph in Peltigeraceae is known to occur in nature under certain environmental conditions, the cyanomorph being more robust than the chloromorph (Goffinet and Bayer 1997).

Conclusions

Considering the young age of the New Botanical Garden of the University of Zürich the number of lichen species found is surprisingly high. Epiphytic lichens of the city of Zürich and surroundings were investigated by Vareschi (1936), Ritschel (1976) and Züst (1977), the latter reports being published at the time when the New Botanical Garden was officially opened. Vareschi (1936) found 39 foliose and 20 crustose species, many of which were already missing in 1977 and are no longer present in the city area. As most of the crustose species were not identified at species level by Züst (1977) and several new species were described in recent years the data sets can not be compared to our present data. Today the majority of foliose and fruticose species, as listed in the 1936 survey on epiphytic lichens in the city of Zürich, can be found in the New Botanical Garden, with some species missing here and probably in the whole area of the city and surroundings, and with few newcomers. Missing at our study site, which is located in one of the least polluted open parkland areas of the city, are pollution sensitive and/or oceanic species, such as the beard lichens (*Usnea filipendula, U. hirta* and *Bryoria fuscata*), the band-shaped *Anaptychia ciliaris* and *Ramalina fastigiata*. The latter were only rarely found in the surroundings of the city in 1936 and nowadays are rare in wide areas of Switzerland. Among Parmeliaceae, *Parmelina quercina* (now rare in wide areas of Switzerland), *Melanelia glabra* and the oceanic *Menegazzia pertusa* are missing in the New Botanical Garden and, with high probability, in the whole city area. Among the newcomers are *Xanthoria polycarpa*, by now a quite common, nitrophilous epiphytic species in the city and surroundings but not mentioned by Vareschi (1936), Ritschel (1976), or Züst (1977), together with the less common *Xanthoria candelaria*, and the oligotrophic (but possibly overlooked) *Melanelia elegantula. Parmotrema perlatum* and *Flavoparmelia soredians* are among the most recent immigrants. The latter one is here reported for the first time from Switzerland. It grows already on several different trees in the garden. Both are present with only one or a few thalli, clearly less than 5 years old. *Parmotrema perlatum* is currently Red Listed (vulnerable), but in most Western European countries it is increasing rapidly now after a period of decline. This increase has been attributed largely to global warming (van Herk et al. 2002). The same applies for *Flavoparmelia soredians*. Similar changes were reported for lichens in other

European cities. From the mid 1980ties onwards various authors documented the return of lichens to city areas following reduction of sulphur dioxide emissions (Kandler and Poelt 1984; Letrouit-Galinou et al. 1992; Seaward 1997; van Herk 2001). However, due to continuous, substantial nitrogen input many of the formerly present, oligotrophic species are missing, but nitrophilous residents and newcomers became common and widespread and may even be used for monitoring ammonia pollution (van Herk 1999). Global warming is an additional factor influencing lichen growth and development. From 1902 to 2002 the mean annual temperature in the city of Zürich raised from 7.6 to 10.4°C, with 8° in 1936 and 8.5°C in 1977, highest increases being recorded from 1997 onwards (Bosshard 2003). Due to global warming some of the psychrophilic lichens were shown to retreat to colder arctic/alpine habitats, whereas xerophilic species invade new areas (van Herk et al. 2002). Elevated temperatures correlate with lower air humidity, presumably one among other reasons why lichen species, which require high humidity, became rare not only in the city of Zürich, but in large areas of Switzerland.

This inventory shows that lichens would be distinctly more common even in the city area when allowed to grow without major disturbance. High pressure cleaning of rock and concrete surfaces and pesticide applications, as often practised in this area, may give the illusion of cleanness. However, the aesthetically very pleasing and well maintained Botanical Garden of the University of Zürich impressively demonstrates that diversity, not cleanness and sterility make a site interesting and beautiful.

Zusammenfassung

Die Flechtenflora des nunmehr 30 Jahre alten Neuen Botanischen Gartens der Universität Zürich wurde untersucht. Insgesamt 149 Arten Flechten bildender Ascomyceten wurden gefunden, darunter auf der Roten Liste stehende Arten wie *Arthonia dispersa* und *Parmotrema perlatum.* Folgende Flechtenarten wurden erstmals für die Schweiz nachgewiesen: *Bacidia adastra, Flavoparmelia soredians* und *Lecanora xanthostoma*. Achtzehn flechtenbildende und zwei nicht-lichenisierte Ascomyceten-Arten wurden erstmals im Kanton Zürich gefunden. Die vorliegenden Daten wurden mit Kartierungsstudien epiphytischer Flechten im Gebiet der Stadt Zürich aus der ersten und zweiten Hälfte des 20. Jahrhunderts verglichen. Im schattigsten und feuchtesten Teil des Gartens wurden mehrere *Peltigera*-Arten angesiedelt und deren Wachstum und Entwicklung dokumentiert. Die spontan aufgetretenen und angesiedelten Flechtenarten im Zürcher Botanischen Garten machen zusammen knapp 10 % aller für die Schweiz nachgewiesenen Flechtenarten aus.

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References

Aptroot A., Sparrius L.B., van Herk C.M. and de Bruyn U. 2001. Origin and distribution of recently described lichens from the Netherlands. Aktuelle Lichenol. Mitt. NF 5: 13 – 25.

Barkman J.J. 1958. Phytosociology and ecology of cryptogamic epiphytes. Van Gorcum, Assen NL.
Bosshard F. 2003. Das Wetter im Jahr 2002. statistic.info 17, Statistisches Amt des Kantons Zürich. http//www.statistik.zh.ch/statistik.info/pdf/2003_17.pdf
Clerc P. 2004. Les champignons lichénisés de Suisse. Cryptogam. Helv. 19: 1 – 320.
Dietrich M. 2006. Die mittelalterliche Museggmauer in Luzern (Zentralschweiz) und ihre Vielfalt an gesteinsbewohnenden Flechten. Meylania 35: 16 – 21.
Goffinet B. and Bayer R.J. 1997. Characterization of mycobionts of photomorphic pairs in the Peltigerineae (lichenized ascomycetes) based on internal transcribed spacer sequences of the nuclear ribosomal DNA. FGBI 21: 228 – 237.
Honegger R., Conconi S. and Kutasi V. 1996. Field studies on growth and regenerative capacity in the foliose lichen *Xanthoria parietina* (Teloschistales, Ascomycotina). Bot. Acta 106: 187 – 193.
Kandler O. and Poelt J. 1984. Wiederbesiedlung der Innenstadt von München durch Flechten. Nat.wiss. Rundsch. 37: 90 – 95.
Letrouit-Galinou M.-A., Seaward M.R.D. and Deruelle S. 1992. A propos des lichens épiphytes dans le jardin de Luxembourg (Paris). Bull. Soc. Bot. Fr. 139, Lettres bot. (2): 115 – 126.
Purvis O.W., Coppins B.J., Hawksworth D.L., James P.W. and Moore D.M. (eds.) 1992. The lichen flora of Great Britain and Ireland. Nat. Hist. Mus. Publ. London.
Ritschel G. 1976. Neue und wenig beachtete epiphytische Flechten im Stadtgebiet von Zürich. Herzogia 4: 33 – 46.
Scheidegger C. and Clerc P. 2002. Rote Liste der gefährdeten Arten der Schweiz: Baum- und erdbewohnende Flechten. BUWAL-Reihe Vollzug Umwelt.
Scherrer S., Zippler U. and Honegger R. 2005. Characterization of the mating-type locus in the genus *Xanthoria* (lichen-forming ascomycetes, Lecanoromycetes). Fungal Genet. Biol. 42: 976 – 988.
Seaward M.R.D. 1997. Urban deserts bloom: a lichen renaissance. Bibl. Lichenol. 67: 297 – 309
Stizenberger E. 1882 – 83. Lichenes Helvetici eorumque stationes et distributio. Jahrb. St. Gallische Nat.wiss. Ges. 22: 255 – 522.
van Herk C.M. 1999. Mapping of ammonia pollution with epiphytic lichens in the Netherlands. Lichenologist 31: 9 – 20.
van Herk C.M. 2001. Bark pH and susceptibility to toxic air pollutants as independent causes of changes in epiphytic lichen composition in space and time. Lichenologist 33: 419 – 441.
van Herk C. M. and Aptroot A. 2004. Korstmossen. KNNV Uitgeverij, Utrecht.
van Herk C. M., Aptroot A. and van Dobben H. F. 2002. Long-term monitoring in the Netherlands suggests that lichens respond to global warming. Lichenologist 34: 141 – 152.
Vareschi V. 1936. Die Epiphyten-Vegetation von Zürich. Ber. Schweiz. Bot. Ges. 46: 445 – 488.
Wirth V. 1995. Die Flechten Baden-Württembergs. 2 Bände. Ulmer, Stuttgart.
Züst S. 1977. Die Epiphytenvegetation im Raume Zürich als Indikator der Umweltbelastung. Veröff. Geobot. Inst. Rübel 62: 1 – 113.