



Tropical urban lichens: observations from Singapore

H.J.M. Sipman¹

Key words

biodiversity conservation
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Abstract The known lichen diversity of Singapore, 296 species, is comparable with temperate lowland areas, but the taxa involved are different, even at high taxonomic levels: the commonest orders are *Arthoniales* and *Graphidales* instead of *Lecanorales*. Epiphytic species dominate, while saxicolous and terrestrial species are rare. Comparison with pre-2000 records and non-urbanized areas suggests a decrease in forest lichens, cyanophilous macrolichens, and the nitrophilous family *Physciaceae*.

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INTRODUCTION

In recent decades large-scale urbanisation has become a widespread feature in tropical areas, and Singapore is a well-known example. Since urbanized areas worldwide are expanding rapidly and thus becoming more and more important for the conservation of biodiversity, a study of the biota of Singapore seems of particular interest. The city is very suitable for such a study because it has received regular attention from biologists during its development from primary lowland forest with small settlements in c. 1800 to extensive plantations a century later and to the present urbanized area interspersed by parks and forest remnants. Resulting publications dealing with lichenized fungi include, e.g., Krempelhuber (1875), Nylander & Crombie (1884), Nylander (1891). An evaluation of the literature and fieldwork in 2000 had as result that now 296 lichen species are known from the area (Sipman in press). The present study provides a comparison with the lichen flora of temperate areas and discusses some probable modifications following the urbanisation.

MATERIAL AND METHODS

The evaluated records originate mainly from fieldwork in 2000 by the author in collaboration with Prof. B.C. Tan, Prof. D.H. Murphy and Mrs. Faridah from the National University of Singapore. On 17 localities 962 samples of lichenized fungi were taken, which provided 1126 records when taking into account mixed specimens and field observations. In addition the published literature was searched for lichen records from Singapore, and relevant specimens were borrowed from the herbaria SING and UPS and the private collections of A. Aptroot, P. Diederich and F. Schumm. For a full list of all records see Sipman (in press). The specimens were investigated in the usual way by stereomicroscope and photomicroscope, and selected specimens were analysed by TLC (Orange et al. 2001) in order to establish their identity.

RESULTS AND DISCUSSION

The known lichen flora of Singapore appears to comprise the surprisingly high number of 296 species (Sipman in press), in

spite of the fact that lichens are nowhere very conspicuous. The total figure might even exceed 325, taking into account the remaining unidentified specimens and the probability of overlooked species.

In order to relate this figure to the situation elsewhere in the world, a comparison with similar areas elsewhere in Europe and Asia is made (Table 1). However, similar published inventories appear to be rare, even in the better investigated parts of the temperate zones of the world, and differences in area size, urbanisation and elevational range make the numbers poorly comparable. Two studies in central Sweden (Örnö and Vänge) are available, which concern lowland areas similar to Singapore but of considerably smaller size and less urbanized. They show distinctly higher species numbers. The Norwegian island Vega at the Arctic Circle, more comparable in size but mountainous and hardly urbanized, has a much higher species number, while the Mediterranean island Ikaria, equally mountainous and little urbanized, has only half this number. Two similarly urbanized areas, Berlin and Hong Kong, appear to have similar species numbers in spite of their larger size and thus can be considered to have a poorer lichen flora than Singapore.

The list of commonest species (Table 2) shows that most lichens in Singapore are crustose and that macrolichens (fruticose and foliose lichens) are uncommon: the only such lichen in the list is the foliose *Dirinaria picta*, which however is very closely applied to the substrate and hardly recognizable as a macrolichen. The order *Lecanorales*, dominant in temperate regions, is much less frequent in Singapore; the dominant orders here are *Graphidales* and *Arthoniales*. At family level (Table 3) the difference with temperate regions is even more pronounced: of the 6 commonest families in Singapore 4 belong to *Graphidales* and *Arthoniales*, while in the temperate locality 4 of the 6 commonest families are *Lecanorales*.

Another important difference with the lichen flora in temperate regions is the substrate preference (Table 4). While in temperate regions saxicolous species form the majority (as long as sufficient substrate is available), in Singapore it concerns a small group. Also terricolous species are much better represented in cooler climates and in Singapore they are almost absent. On the contrary, in Singapore the far majority of the lichens are epiphytic and its number far exceeds the numbers of epiphytic lichens for all temperate sites listed by Foucard (2004).

Singapore seems particularly suited to monitor changes in the lichen flora, because its lichenological exploration started early.

¹ Free University of Berlin, Botanischer Garten und Botanisches Museum, Königin-Luise-Strasse 6–8, D-14195 Berlin, Germany.

Table 1 Species numbers of lichenized fungi in selected areas.

Locality	Size (km ²)	Summit (m)	Species nr.	Source
Sweden, Ornö island	48	c. 40	441	Degelius 1942
Sweden, Vänge	30	c. 50	433	Foucard 2004
Norway, Vega island	163	797	668+	Degelius 1982
Greece, Ikaria island	255	910	c. 350	Sipman unpublished
Singapore	693	166	299	present study
Berlin	892	115	290	Sipman & Aptroot 2008
Hong Kong	1098	958	308	Aptroot & Sipman 2001

Table 2 The 31 commonest lichen species of Singapore, with order and number of reports. For pictures see <http://www.bgbm.fu-berlin.de/sipman/Zschackia/Singa/genuslist.htm>.

Species	Order	Number of reports
<i>Arthonia catenulata</i>	Arthoniales	47
<i>Dirinaria picta</i>	Lecanorales	46
<i>Phaeographis intricans</i>	Graphidales	35
<i>Pyrenula ochraceoflava</i>	Pyrenulales	33
<i>Graphis caesiella</i>	Graphidales	32
<i>Ocellularia crocea</i>	Graphidales	28
<i>Ocellularia papillata</i>	Graphidales	22
<i>Graphis hiascens</i>	Graphidales	20
<i>Phaeographis caesioradians</i>	Graphidales	17
<i>Chrysothrix xanthina</i>	Arthoniales	15
<i>Cresponea flava</i>	Arthoniales	14
<i>Trypethelium variolosum</i>	Pyrenulales	13
<i>Lepraria usnica</i>	Lecanorales	13
<i>Cryptothecia scripta</i>	Arthoniales	13
<i>Diorygma rufopruinosum</i>	Graphidales	13
<i>Amandinea efflorescens</i>	Lecanorales	12
<i>Anisomeridium throwerae</i>	Pyrenulales	12
<i>Lecanora helva</i>	Lecanorales	12
<i>Porina tetracerae</i>	Trichotheliales	12
<i>Trypethelium tropicum</i>	Pyrenulales	12
<i>Mycoporum eschweileri</i>	Pyrenulales	10
<i>Pyrrhospora quernea</i>	Lecanorales	10
<i>Trypethelium eluteriae</i>	Pyrenulales	10
<i>Trypethelium epileucodes</i>	Pyrenulales	10
<i>Bactrospora myriadea</i>	Arthoniales	9
<i>Cryptothecia lunulata</i>	Arthoniales	9
<i>Sarcographina glyphiza</i>	Graphidales	9
<i>Cryptothecia granularis</i>	Arthoniales	8
<i>Graphis glaucescens</i>	Graphidales	8
<i>Myriotrema subconforme</i>	Graphidales	8
<i>Trypethelium platystomum</i>	Pyrenulales	8

Table 3 Comparison between the lichen flora of Singapore and Berlin (after Sipman & Aptroot 2008). Shown are species number and 6 commonest families.

Singapore: 299		Berlin: 290	
<i>Graphidaceae</i>	11 %	<i>Cladoniaceae</i>	10 %
<i>Thelotremaaceae</i>	9 %	<i>Lecanoraceae</i>	9 %
<i>Roccellaceae</i>	7 %	<i>Parmeliaceae</i>	8 %
<i>Arthoniaceae</i>	8 %	<i>Teloschistaceae</i>	7 %
<i>Trichotheliaceae</i>	4 %	<i>Verrucariaceae</i>	6 %
<i>Physciaceae</i>	3 %	<i>Physciaceae</i>	5 %

Table 4 Substrate preference of the lichen flora of Singapore and Berlin (after Sipman & Aptroot 2008).

	Singapore	Berlin
Saxicolous	7 %	41 %
Epiphytic	92 %	37 %
Terrestrial	1 %	18 %

Table 5 Comparison of the dominant lichen families in Singapore, a heavily industrialized conurbation, and Madang (Papua New Guinea), an unindustrialized town with similar climate.

Singapore		Madang	
<i>Graphidaceae</i>	16 %	<i>Graphidaceae</i>	22 %
<i>Thelotremaaceae</i>	12 %	<i>Physciaceae</i>	17 %
<i>Roccellaceae</i>	10 %	<i>Pyrenulaceae</i>	15 %
<i>Arthoniaceae</i>	8 %	<i>Roccellaceae</i>	8 %
<i>Trichotheliaceae</i>	5 %	<i>Arthoniaceae</i>	5 %
<i>Physciaceae</i>	5 %	<i>Trypetheliaceae</i>	5 %

The species list (Sipman in press) contains 137 taxa which were observed before 2000. Of these 86 were not refound in 2000. This seems a surprisingly high number in view of the fact that so many additional species were found and the 2000 inventory seems reasonably complete. The following explanations can be postulated for their absence, depending on the date of observation:

1. Species reported before 1900 and not refound afterwards (47 taxa) concern most probably obligate forest species, which disappeared after logging of the forest. Evident cases of species, which were reported in the past from Singapore and are nowadays found only in primary forest relics away from Singapore include, e.g., *Ocellularia triglyphica* and *Thelotrema isidiophorum* (specimens available from Gunung Pulai in Johor, Malaysia). However, in some cases the reports concern poorly-known species of uncertain status, which may eventually appear to be synonyms or misapplied names. The status of such reports can only be ascertained by a re-examination of vouchers, if any are left.
2. Species reported after 1900 (39 taxa) are usually without much doubt about their identity. It may concern uncommon species which have been missed by accident. However, it concerns usually conspicuous macrolichens which have

been observed more than once in the past and are unlikely to be overlooked. A decrease is the most likely explanation for their current scarcity: *Dirinaria* spp., *Collema* spp., *Leptogium* spp., *Physma byrsaeum*. This group includes a particularly conspicuous and easily collectable group of foliose, often gelatinous, epiphytic lichens with cyanobacteria as photobiont ('cyanophilous' species), which are well represented in the herbarium collections but scarcely found in 2000. Such lichens are known from Europe as particularly sensitive to air contamination, and their decrease in Singapore might be an indication for air quality changes. The equally strong evidence for a decrease in *Dirinaria* spp. (cf. Awasthi 1975) is less easily understandable because they belong to the family *Physciaceae*, a group which generally profits from an increase in fixed nitrogen as often observed in urbanized areas. However, also Table 5 suggests a reduction in *Physciaceae* in Singapore.

In a discussion on changes in the lichen flora of Singapore, the deforestation is probably the most important factor to be addressed. From temperate forests it is well-known that a considerable number of lichen species cannot stand the disturbance of clear-felling (e.g., Coppins & Coppins 2006), and there seems no reason why this would be different in the

tropics. Unfortunately, the number of lichen species reported from Singapore before c. 1900, when the primary forests were probably still readily available and logging would have made the sampling of lichens easy, is very limited. Certainly it has not been very representative, because many additional forest lichens have been found in secondary forest (e.g., loc. 10, 11, 12 cf. Sipman in press) in the year 2000, which most probably have been present also before. How many lichen species might have grown in the primary forest cover of the area is difficult to estimate, because there is very little information about the lichen flora of primary forests anywhere in the humid tropics of Southeast Asia. Aptroot (1997) indicates 500 species for lowland primary forest in northern Papua New Guinea and there seems no reason why this figure would be very different in Singapore. If so, several hundred lichen species may have disappeared from Singapore due to the clearing of the primary forest.

Despite the significance of the primary state of forests for lichens, visits in 2000 to the primary forest remnants in the Botanical Garden and on Bukit Timah revealed a poor lichen flora. Lichens were absent from most of the trunks and restricted to tree bases and sheltered valleys, where they were often poorly developed. A freshly fallen, large tree allowed a detailed inspection of the crown with only one species on a sheltered part of the trunk (# 46379, *Ocellularia interponenda*) as result. This differs much from the situation in primary tropical forests away from industrial areas, where the crowns of most trees harbour dozens of species, cf. Komposch & Hafellner (1999), and resembles the situation in temperate areas with high sulphur dioxide pollution, where tree crowns are devoid of lichens. Evidently the primary forest remnants in Singapore have not served as refuges for the lichen diversity of the primary forest.

To assess possible changes in the non-forest lichen flora, unpublished data from the small, unindustrialized town Madang on the north-coast of Papua New Guinea have been used (Table 5). They show a lower representation of *Thelotrema* in Madang, which can be explained because in the inventory of Singapore forest remnants were included. For the lower representation of *Physciaceae* and *Pyrenulaceae* in Singapore there seems no habitat-dependant explanation and it may reflect air quality changes related to urbanization.

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