Species/area curves for lichens on gypsum in Turkey

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Abstract. Twenty-nine lichen species on gypsum soil and crystalline gypsum and five species on plant debris influenced by gypsum in Turkey have been investigated. Six species, *Acarospora nodulosa, Acarospora placodiiformis, Aspicilia lacunosa, Caloplaca thuringiaca, Fulgensia desertorum* and *Lecidea circinarioides* are new to Turkey, some records considerably extending their known distribution. Species/area curves show the localities and the lichen species as highly endangered, with on average 4 localities accounting for 50 % of the detected number of species; 29 species in 10 localities correspond to 75.5 % of the statistical optimum of *ca* 37 species expected in an endless number of plots. In order to account for 90 % of the species, 34 localities need to be investigated. Not only should more localities be searched for and studies, but some of those already investigated need to be protected.

Keywords: biodiversity, conservation, gypsum soil, lichens, species/area curves, Turkey

Introduction

Whilst investigating the lichens of the ancient province of Kappadokia in Central Anatolia, we studied the their communities on gypsum at ten sites. Although lichens on gypsum have been studied in several countries such as Germany, Italy, Morocco, Russia, Spain and Ukraine (Burgaz & Mendiola 1984; Casares-Porcel *et al.* 1994; Ottonello 1995; Poelt *et al.* 1995; Nimis *et al.* 1996), details of their occurrence on this substratum in Turkey are unknown.

Calcium sulphate is a soil-building mineral occurring in nature as gypsum ($CaSO_4 \cdot 2H_2O$) or as the anhydrite ($CaSO_4$). Gypsum is particularly affected by weathering, but this is only effective in the presence of water and at temperatures above 0 °C; at 20 °C, *ca* 2.6 g of gypsum is dissolved in 1 litre of water (Scheffer & Schachtschabel 1960). Usually, such conditions do not exist in Inner Anatolia: although the summer is hot enough, water is lacking, and in winter, water is available, but temperatures are below 0°C. Hence, gypsum is less heavily affected by weathering in Anatolia than elsewhere in Turkey and other countries.

The soils over gypsum are rendzinas, which are highly acidic in their early development. As the initial material consists of almost pure mineral, no clay material persists. The upper humus layer and the clefts within the substratum below are very poor reservoirs for water. This is a significant disadvantage for their agricultural use (Mückenhausen 1959). However, in Turkey, the pressure of extending land use for economic purposes is so immense that even such poor soils are ploughed up and nutrient deficits hopefully compensated by synthetic fertilizers. The extension of agriculture to non-profitable soils and grazing by larger herds leads to detrimental nitrification.

As the localities of undisturbed gypsum soils in Turkey are restricted to very small areas and are rather scattered, a detailed survey of their lichen communities is highly desirable. Hyperbolic cumulative species/area curves are useful instruments for determining species diversity, minimal area and species density (Schmitt 1999, 2001). As exemplified by work on higher fungi and other organisms, species/area curves are valuable tools when applied to nature protection, ecosociology, mapping procedures and monitoring changes (Schmitt 1999).

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Material and Methods

The sites studied (Fig. 1) occur at altitudes ranging from 1275 to 1750 m where the climate is typical for the Inner Anatolian plateau (Fig. 2). Each area (*ca* 10 m × 10 m) was investigated for *ca* 30-45 minutes at each site; such standards were necessary for the statistical analysis. The mathematical procedure of the "rot-10-statistics" (Table 2) was processed according to Schmitt (1999, 2001). The best hyperbola for the species-sum (y) and the plot-sum (x) follows the formula: $y = (R \times x) / (M + x)$, where R = maximum species number and M = minimum plot number.

Collecting sites (see Fig. 1)

① Prov. Ankara (06), open hills in agricultural area, *ca* 2 km E of Bala, 39°32' N, 33°08' E, alt. 1275 m, 7 Jul 2001.
② Prov. Sivas (58), open hills near a roadside, *ca* 6 km W of Hafik, 39°49' N, 37°17' E, alt. 1350 m, 14 Jul 2001.
③ Prov. Sivas (58), open hills near a roadside, *ca* 14 km W of Imranlı, 39°52' N, 37°57' E, alt. 1650 m, 14 Jul 2001.
④ Prov. Sivas (58), mountains W of the Çorakboğazı - Karacaören road, 39°46' N, 38°09' E, alt. 1750 m, 14 Jul 2001.
⑤ Prov. Sivas (58), open hills on E shore of Tötürge Gölü, W of Zara, 39°52' N, 37°36' E, alt. 1300 m, 14 Jul 2001.
⑥ Prov. Sivas (58), S-exposed hills near Barit Alanı, Budaklı, S of Sivas, 39°35' N, 37°02' E, alt. 1370 m, 1 Aug 2002.
⑦ Prov. Sivas (58), exposed hills near Karayün, SE of Sivas, 39°40' N, 37°18' E, alt. 1470 m, 1 Aug 2002.
⑧ Prov. Sivas (58), flat hills SE of Kovalı, S of Sivas, 39°31' N, 37°01' E, alt. 1350 m, 1 Aug 2002.
⑨ Prov. Sivas (58), exposed hills near Cekem, between Sivas and Şarkışla, 39°27' N, 36°34' E, alt. 1530 m, 2 Aug 2002.
⑩ Prov. Kayseri (38), mountains *ca* 5 km W of Tuzla Gölü, NE of Kayseri, 39°04' N, 35°49' E, alt. 1250 m, 2 Aug 2002.

Results

Twenty-nine lichen taxa were recorded as growing directly on gypsum soil (e.g. *Acarospora placodiiformis, Aspicilia hispida, A. lacunose, Diploschistes diacapsis, Fulgensia desertorum, Psora decipiens, P. saviczii, Squamarina lentigera, Toninia physaroides, T. sedifolia*) and gypsum minerals (e.g. *Aspicilia contorta* subsp. *hoffmanniana, Caloplaca lactea, C. trachyphylla, Lecanora crenulata, Lecidea circinarioides, Physcia dimidiata, Protoparmeliopsis muralis*), and five species occurred on dead twigs of *Thymus* sp. influenced by the gypsaceous substratum (Table 1). Six taxa, *Acarospora nodulosa, Acarospora placodiiformis, Aspicilia lacunosa, Caloplaca thuringiaca, Fulgensia desertorum* and *Lecidea circinarioides,* are recorded for the first time from Turkey. Other species noted during this investigation, *Acarospora reagens, Caloplaca trachyphylla* and *Psora savicii*, have been distributed in *Lichenes Anatolici Exsiccati* (John 2002).

Figure 3 shows the increase in species number relative to the number of sites studied, the number of species processed in the statistical analyses being 29 and the number of plots (localities) 10. The maximum species number R of the asymptote (for an endless number of plots) is 37.4±1.6, which means that 36 to 39 species can be expected on gypsum soil in Turkey.

Three to four locations (3.2±0.4), which include 50 % of all species, is defined as the minimal area. A total of 29 species detected in the 10 areas studied account for 75.5 % of the optimum number of species expected. If 90 % of the maximum species number R are targetted, then 34 plots (localities) need to be investigated.

Notes on selected species

Acarospora reagens
Observations confirm the situation in most of the other countries where *A. reagens* is more frequent than *A. nodulosa.*

Acarospora placodiiformis
It is remarkable that all samples in all localities were sterile. Even at station nr. 6, where it dominated the substratum, no specimens with apothecia were detected. Guerra *et al.* (1995) correlated this phenomenon to an increase in temperature. The taxon was first regarded as endemic to the Iberian Peninsula (Egea & Alonso 1996), but was later recorded from Italy (Nimis *et al.* 1996).

Caloplaca thuringiaca
This recently described species (Søchting & Stordeur 2001) was previously known only from Germany, Switzerland, Austria and Italy (Stordeur 2003). It grows on dead branches lying adjacent to ground influenced by gypsum. Note the gaps in localities 1 to 6, where this kind of substratum was not investigated.

Caloplaca trachyphylla
This lichen, likely to be confused with *Xanthoria elegans,* is not rare in Central Anatolia. The ecology in this area corresponds to that of other habitats of this species in Asia (Khodosovtsev *et al.* 2004) and North America (Brodo *et al.* 2001). Thalli grow on gypsum minerals but not on gypsum soil. Outside the gypsum areas in Turkey, it grows on exposed horizontal calcicolous rocks.

Collema coccophorum
This taxon is widespread but rare on bare soil (Degelius 1954, 1974) and in the European Community it has been classified as vulnerable (Sérusiaux 1989).

Diploschistes diacapsis
This is one of the most frequent species in the studied area in terms of abundance and dominance. The habitat of this

Table 1. List of lichens on gypsum soil and their distribution in ten locations in Turkey

Species	Number of location (see Fig. 1)									
	1	2	3	4	5	6	7	8	9	10
Acarospora nodulosa (Dufour) Hue							+			
Acarospora placodiiformis H. Magn.						+		+		
Acarospora reagens Zahlbr.		+			+	+	+	+	+	
Aspicilia contorta subsp. *hoffmanniana* Ekman & Fröberg		+				+		+	+	+
Aspicilia desertorum (Kremp.) Mereschk.		+				+				
Aspicilia hispida Mereschk.					+		+			
Aspicilia lacunosa Mereschk.										
Caloplaca lactea (A.Massal.) Zahlbr.						+		+		
Caloplaca trachyphylla (Tuck.) Zahlbr.									+	
Candelariella aurella (Hoffm.) Zahlbr.							+			
Collema coccophorum Tuck.			+							
Collema crispum (Huds.) Wigg.		+						+		
Collema tenax (Sw.) Ach. emend. Degel.	+	+		+	+		+	+		
Diploschistes diacapsis (Ach.) Lumbsch			+		+	+	+	+	+	+
Diploschistes muscorum (Scop.) R. Sant.							+			
Fulgensia bracteata (Hoffm.) Räsänen	+	+	+		+	+	+	+	+	+
Fulgensia desertorum (Tomin) Poelt						+	+	+	+	+
Fulgensia subbracteata (Nyl.) Poelt					+					
Lecanora crenulata (Dicks.) Hook.					+		+	+		
Lecidea circinarioides Casares & Hafellner						+	+		+	
Lepraria vouauxii (Hue) R.C. Harris		+							+	
Physcia dimidiata (Arnold) Nyl.									+	
Placidium squamulosum (Ach.) Breuss		+	+	+	+		+		+	
Protoparmeliopsis muralis (Schreb.) M.Choisy	+									
Psora decipiens (Hedw.) Hoffm.	+	+	+	+	+	+	+	+	+	+
Psora saviczii (Tomin) Follmann & Crespo	+	+	+	+	+	+	+	+	+	+
Squamarina lentigera (Weber) Poelt		+					+	+		+
Toninia physaroides (Opiz) Zahlbr.	+	+	+		+		+		+	
Toninia sedifolia (Scop.) Timdal						+	+			
On thin dead twigs of *Thymus* sp. near the ground:										
Caloplaca thuringiaca Søchting & Stordeur		+					+	+	+	+
Candelariella aurella (Hoffm.) Zahlbr.							+			
Candelariella unilocularis (Elenkin) Nimis									+	
Lecania koerberiana Lahm								+	+	+
Lecanora hagenii (Ach.) Ach.							+	+		+

Table 2. Baseline information for the "rot-10-statistics"

Plot Σ	1-10	2-10-1	3-10-2	4-10-3	5-10-4	6-10-5	7-10-6	8-10-7	9-10-8	10-9
	1	2	3	4	5	6	7	8	9	10
1	6	12	7	4	11	12	17	13	13	7
2	13	14	8	11	18	21	21	19	14	10
3	15	14	12	18	22	22	24	19	16	15
4	15	17	19	22	23	25	24	20	18	16
5	18	23	23	23	26	25	25	21	19	16
6	24	26	24	26	26	26	26	22	19	19
7	27	26	27	26	27	27	27	22	22	24
8	27	28	27	27	28	28	27	24	26	27
9	29	28	28	28	29	28	29	26	29	27
10	29	29	29	29	29	29	29	29	29	29

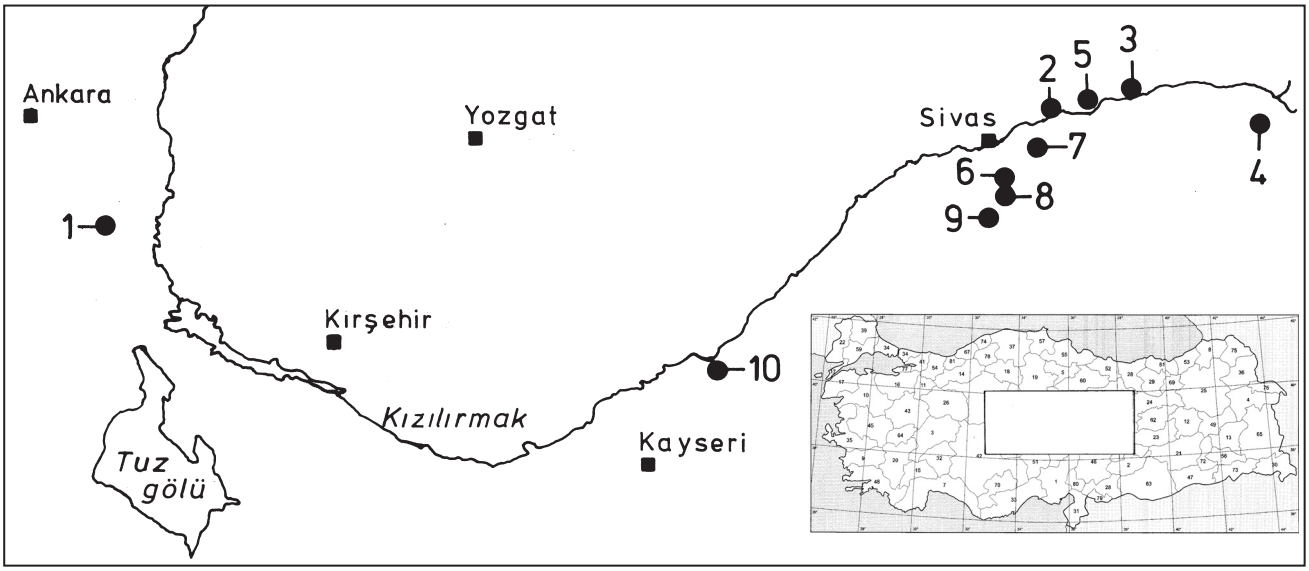

Fig. 1. Study area and collecting sites

variable species, which also grows on calcareous soil (Lumbsch 1988), is rather constant here on the typical form on gypsum (Lumbsch 1989).

Lecidea circinarioides
This species, formerly known only from Spain and Morocco (Casares-Porcel *et al.* 1996), was found with rather small thalli and with a very low abundance.
Psora saviczii
This lichen, formerly known from China, Germany, France, Italy, Macedonia, Morocco, Russia, Spain and Ukraine (Poelt *et al.* 1995; Schneider 1979), is highly stetic on gypsum soil and together with *P. decipiens* are the only species found in all localities investigated. Also the number of thalli found in all sites was higher with great abundance.

Conclusions

Although gypsum soil is extremely poor in nutrients, it has been ploughed in two places visited (localities 1 and 10). In the other places, not used in agriculture, the areas are heavily overgrazed by sheep and goats. Therefore it is almost impossible to find areas with undisturbed vegetation. As the localities are destroyed and the cover by lichens is restricted to small areas, in many cases no larger than 10 m to 10 m, the lichens and their habitats are endangered. At localities 2 and 3, two of the studied areas have recently been intersected by a road. Other localities suffer from the direct influence of adjacent villages (locality 7) and industrial areas (locality 6). These factors and influences create a mosaic of lichen associations with a rather different composition of species and completeness of taxa. The study shows that hitherto only 75 % of the expected total of about 36 to 39 taxa has been recorded.

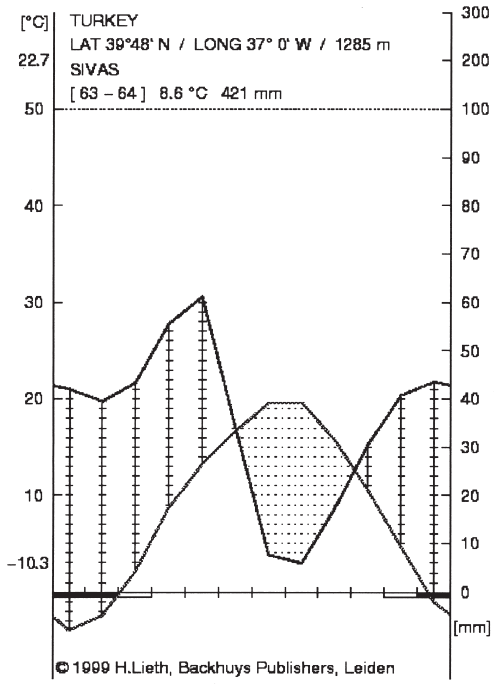

Fig. 2. Climate diagram of Sivas (from Lieth *et al.* 1999)

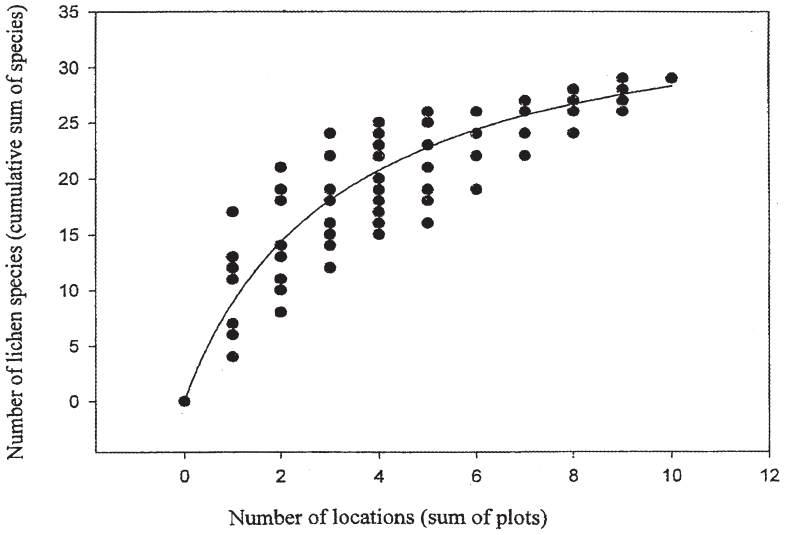

Fig. 3. Statistical analyses showing the increase of species number in correlation to the number of sites studied (some plots are multiple in the graphic)

Eight species were observed in one locality only, most of which are common and widespread (*Aspicilia desertorum, A. hispida, Candelariella aurella, Protoparmeliopsis muralis*), normally growing on calcareous rocks and soil, and exceptionally invading on gypsum. On the one hand, this points to gypsum as being a hostile substratum for many unadapted lichens, and on the other hand, it favours some species, the records showing considerable extensions of the known area (*Acarospora placodiiformis*) or representing a link between areas in the Iberian Peninsula and Central Asia.

According to the categories proposed by IUCN, some of the lichens on gypsum must be regarded as rare, vulnerable, or endangered (Guerra *et al* 1995). Agriculture, grazing, road construction, etc. are harmful to the lichens on gypsum soil, therefore management protection strategies are recommended. It is not misleading to include military areas in natural protecting programs with the condition that gregarious animals will be kept locked out. The statistical method used shows that a protection of a sum of four areas in each case is applied for only 50 % of all species.

Further studies are required to define a more distinctive mosaic with a sufficiently close network of localities. If the aim of the study is to detect 90 % of all expected species, 24 further localities must be found and studied. Consequently, such a network of 34 areas will describe sufficiently close connections and allow for the exchange of lichen diaspores and thus their survival.

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