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Biomonitoring of air pollution by lichen diversity in the urban area of Setif, Algeria

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Abstract. *Belguidoum A, Haichour R, Lograda T, Ramdani M. 2022. Biomonitoring of air pollution by lichen diversity in the urban area of Setif, Algeria. Biodiversitas 23: 970-981.* The use of living organisms in air quality monitoring has received increasing attention in recent years. Lichens, pioneer and colonizing organisms, are directly sensitive to environmental changes. This results in a loss of vitality or complete destruction of the thallus. The objective of this study is to assess and map the air quality of the Setif region, Algeria by lichens, using bio-indication indices. For air quality assessment, lichen species frequency, the Shannon-Wiener index, Atmospheric Purity Index (IAP), and Air Quality Index (IAQ) were used. Sixty stations were sampled across the region, representing the various level of landscape factors and anthropogenic activities. The study recorded 54 lichen species in urban areas of Setif belonged to 29 genera and 19 families, of which crustose and foliose, were the most common in the region. The pollution indicators (IAP, IAQ) showed an important correlation between them and a difference between rural and urban ecosystems. Anthropized urban areas showed very high air pollution. This is probably due to industrial and agricultural activities, but especially to gas emissions from vehicles. The majority of studied stations belonged to an area with very high atmospheric pollution. In addition, the presence of the species *Xanthoria parietina* in all the stations studied facilitates to use it as a reliable biomonitor of plant tolerance to pollutants in urban ecosystems.

Keywords: Algeria, biodiversity, biomonitoring, lichens, pollution index, Setif

INTRODUCTION

There are various air contaminants in urban settings, including Carbon Monoxide (CO), particulate matter (PM), nitrogen dioxide (NO_2), Sulfur Dioxide (SO_2), Ozone (O_3) and Metal trace element (MTE) (Cichowicz and Stelęgowski 2019). Such contaminants act together, making it difficult to discern their effect on humans or the environment. Nonetheless, among them, atmospheric pollutant emission from road traffic is regarded as the main source of air pollution in cities around the world (Fioravanti et al. 2018; Hankey and Marshall 2017). These contaminants compounds are also widely distributed in the environment due to industrial activities, mining, and domestic emissions, but above all, by intensive agricultural activities (Deshmukh et al. 2020; Huo et al. 2014).

Air pollution requires the implementation of air quality monitoring. There are several methods to monitor air quality, including multivariate physico-chemical analysis, based on air pollution monitoring system and air quality control by network facilities, and biological techniques (Conti and Cecchetti 2001; Khedo et al. 2010; Shaban et al. 2016). Relatively few studies have relied on the concurrent use of biomonitoring (Belguidoum et al. 2021; Kaur and Nagpal 2017). Living organisms used in air quality monitoring offer an important tool for estimating the impact of air pollution, providing data for environmental management (Pirintsos and Loppi 2008).

Using lichens as bioindicators helps to understand the state and impact of pollutants on the atmospheric environment. The lichen is a symbiotic organism formed by a fungal partner (mycobiont) and a photosynthetic organism (photobiont) that join. Lichens do not have stomata or cuticles to regulate air exchange, thus these organisms can integrate the effects of air pollution over time (Conti and Cecchetti 2001; Nimis et al. 2002). The lichens are very efficient bio accumulators in trapping trace metal elements from the atmosphere (Bargagli 2016; Belguidoum et al. 2021a,b; Will-Wolf et al. 2017). Due to their physiological characteristics sensitivity to pollution, combined with their ability to grow over large geographical areas, lichens are classified as a reliable and ideal bio-integrator for assessing air pollution (Antonucci et al. 2016; Loppi 2019).

Epiphytic lichens provide spatial and temporal evidence for the abilities of air pollutant loadings due to increasing levels of gases and dust emissions released into the atmosphere (Loppi 2014). Lichens also provide information on the impact of air pollution on organisms. They are easy and inexpensive to use and provide results on which human health deductions can be based (Cislaghi and Nimis 1997). Considering the above-mentioned advantages, many countries use bioindication indices based on the diversity and spatial distribution of lichens to estimate air pollution levels (Agnan et al. 2017; Biazrov 2013; Belguidoum et al. 2021; Dron et al. 2016; Jayalal et al. 2016; Kirschbaum et al. 2012; Klymenko 2015; Kricke and Loppi 2002).

The Setif province is an agglomeration located in the northeast of Algeria with an area of 6500 km². It is considered a strategic transit zone as a set of important roads crosses it: National Road No. 5, which connects the capital to the provinces of north-eastern Algeria; and the national roads No. 09, No. 28, and the national road No. 78, ensuring the connection of the northern provinces to the southern provinces. The highway in the region connects eastern Algeria to the west. The region is also an important industrial and commercial hub.

Considering the situation of Setif region, which is potentially exposed to air pollution mainly from road traffics, there is a need to study the state of air quality of the region. The aim of this study is to monitor and map the air quality of the Setif region using bio indication indices through lichen flora by relating it with the atmospheric purity index (IAP) and the air quality index (IAQ).

MATERIALS AND METHODS

Study area

This study was conducted in Setif region, Algeria (Figure 1). The climate of the Setif region is a semi-arid continental type with summers are hot and dry and winters are harsh. Annual rainfall in Setif varies between 300 and 700 mm/year. The study area has an elevation of 505 to 2004 meters above sea level (asl).

Epiphytic lichens from the Setif region were sampled in 60 localities (municipalities) (Figure 1). The geographical coordinates of the sampled stations are mentioned in Table 1.

Sampling procedure

The study was conducted in Setif Province, Algeria. The samples of the urban station were selected based on the presence of suitable phorophytes on which lichens can be observed. Trees chosen for lichen collection were found under the same conditions (trunk diameter, light, humidity and wind exposure). In each station, six trees were selected and sampled. The survey was carried out within an area of 20 x 50 cm (on the tree trunk) with a transparent plastic of 20 by 50 cm in size, comprising 10 cases of 10 x 10 cm each allowing the frequency of each species to be quickly defined on the trunk. The survey grid was placed at an average height of 100 to 150 cm to avoid contamination due to animal droppings or soil chemicals. This work was carried out during the period of 2020-2021. Lichen sampling was performed by applying the method of Kirschbaum and Wirth (1997).

The lichens that present difficulties in in-situ determination, their whole thalli or a representative fragment with the peripheral part and the central part were collected. The samples were placed in paper bags, labeled with the number and the name of the site, and then transported to the laboratory. In the laboratory, the lichen samples were observed in detail using a binocular (Optika) and a light microscope (Aksioscop 40, Zeiss; magnification, 40X). Chemical spot tests were applied to samples that were difficult to identify.

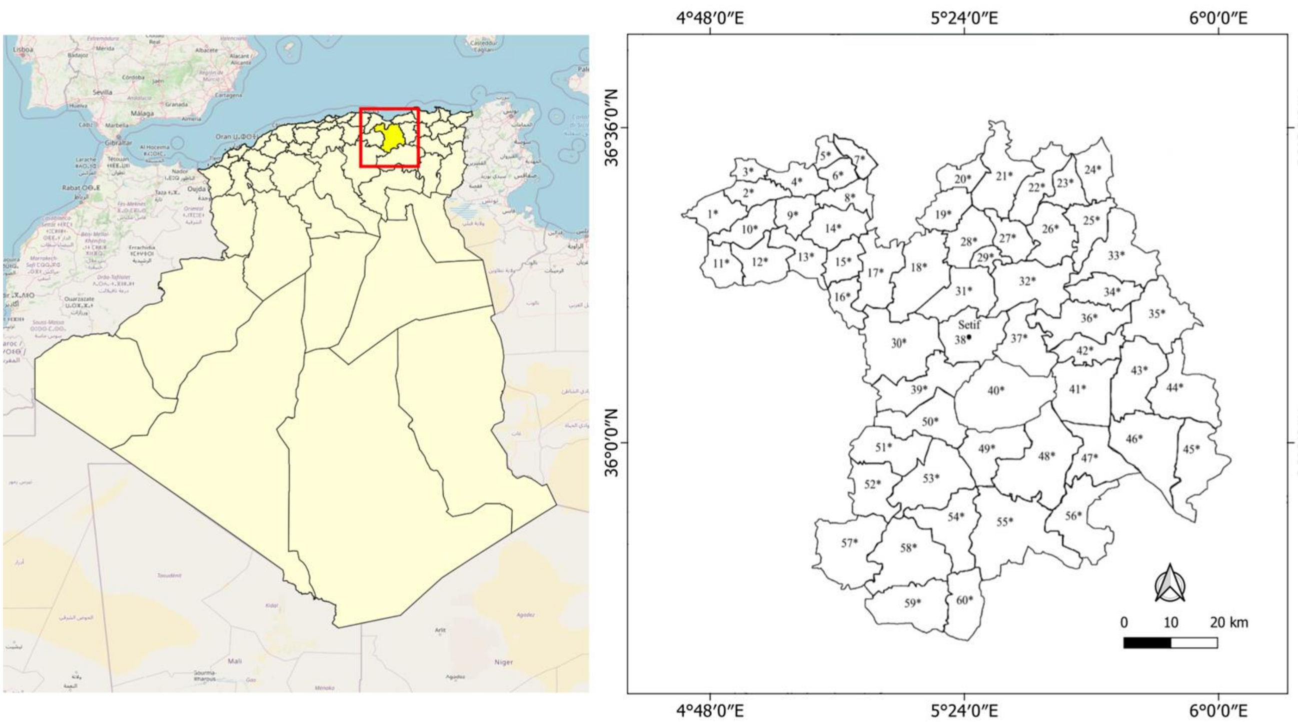

Figure 1. Map of 60 sampling sites in the study area in Setif region, Algeria

Table 1. Geographical information of each sampling location in Setif region, Algeria

	Localities	Latitude N	Longitude E	Alt. (m)
1	Beni Ouartilene	36°26′00″	4°54′00″	900
2	Beni Chebana	36°27′54″	4°52′34″	750
3	Beni Mouhli	36°30′27″	4°54′54″	802
4	Bousselam	36°29′39″	5°02′37″	992
5	Aït Naoual Mezada	36°32'32"	5°05'24"	500
6	Bouandas	36°29′41″	5°06′07″	901
7	Aït Tizi	36°33′32″	5°07′38″	1009
8	Tala Ifacene	36°27′30″	5°05′20″	908
9	Draa Kebila	36°26′11″	4°59′44″	900
10	Aïn Legradj	36°24′35″	4°53′28″	780
11	Guenzet	36°19′00″	4°50′00″	900
12	Harbil	36°19′30″	4°55′35″	740
13	Hamam Guergour	36°19′00″	5°04′00″	647
14	Maoklane	36°23′50″	5°04′31″	950
15	Bougaa	36°19′57″	5°05′19″	840
16	Beni Ouacine	36°16′20″	5°07′39″	855
17	Aïn Roua	36°20′04″	5°10′50″	900
18	Aïn Abessa	36°18'00"	5°17'42"	1005
19	Tizi n'Bechar	36°25′52″	5°21′36″	895
20	Oued Barad	36°28′36″	5°24′05″	1050
21	Babor	36°29′25″	5°32′24″	1180
22	Serdj Ghoul	36°28′41″	5°34′38″	980
23	Beni Aziz	36°28′00″	5°39′00″	1004
24	Aïn Sebt	36°28′54″	5°42′40″	1070
25	Maaouia	36°23′20″	5°42′36″	905
26	Dehamcha	36°22′56″	5°35′43″	995
27	Aïn Kebira	36°21′53″	5°30′07″	980
28	Amoucha	36°23′17″	5°24′39″	800
29	Ouled Addouane	36°20′24″	5°28′28″	1055
30	Aïn Arnat	36°11'00"	5°19'00"	1018
31	Ouricia	36°17′01″	5°24′34″	1138
32	Beni Fouda	36°17′10″	5°36′26″	690
33	Djemila	36°19′01″	5°44′07″	897
34	Tachouda	36°15′45″	5°42′47″	899
35	Belaa	36°12′09″	5°51′13″	670
36	Guelta Zerka	36°12′32″	5°41′16″	986
37	Ouled Saber	36°12′00″	5°31′00″	1075
38	Setif	36°09′00″	5°26′00″	1100
39	Mezloug	36°06′28″	5°20′13″	915
40	Guedjel	36°07′06″	5°31′48″	950
41	Bazer Sakhra	36°07′00″	5°42′40″	705
42	El Eulma	36°09′23″	5°41′06″	950
43	Bir Arch	36°08′00″	5°50′00″	920
44	Ouldja	36°03′49″	5°57′13″	820
45	Taya	35°58′17″	5°57′23″	800
46	Hamam Soukhna	35°58′37″	5°48′32″	655
47	Tella	36°00′25″	5°43′04″	680
48	Aïn Lahdjar	35°56′14″	5°32′32″	689
49	Bir Haddada	35°57′46″	5°25′51″	505
50	Guellal	36°02′42″	5°19′41″	905
51	Ksar Abtal	35°58′27″	5°17′17″	800
52	Ouled Si Ahmed	35°54′04″	5°11′30″	1080
53	Aïn Oulmene	35°54′00″	5°17′00″	928
54	Salah Bey	35°51′15″	5°17′30″	974
55	Aïn Azel	35°50′36″	5°31′19″	706
56	Beidha Bordj	35°53′39″	5°39′49″	880
57	Ouled Tebben	35°48′46″	5°06′05″	1007
58	Rasfa	35°48′37″	5°15′55″	620
59	Boutaleb	35°39′37″	5°19′16″	1202
60	Hamma	35°40′50″	5°22′22″	980

Identification of the lichens was referred to several books (Jahns 2011; Roux et al. 2017; Tiévant 2001; Van Haluwyn et al. 2013); as well as websites (French Association of Lichenology) (http://www.aflllichenologie.fr), LIAS light - A Database for Rapid Identification of Lichens (http://liaslight.lias.net/) and the British Lichen Society (https://www.britishlichensociety.org.uk/). Specimens of the identified lichens were kept in the herbarium of the VRBN Laboratory of the Faculty of Nature and Life Sciences. Each species sampled were assigned a recovery coefficient.

Index calculations

The Shannon-Weaver diversity index (H')

Shannon Index is a commonly used diversity index that takes into account both abundance and evenness of species present in a station (Shannon and Weaver 1949). It is expressed by the formula:

$$H' = \sum_{i=1}^{i=n} (Pi * lnPi)$$

Where: *H'*: Diversity; *i*: lichenic species; *Pi*: the proportional abundance of *i* species*; n:* total number of species observed.

The index of atmospheric quality (IAQ)

To assess the global pollution in the Setif region, the German air quality index (IAQ) method was applied. This index is based on the sum of the average frequencies found on six trees (Kirschbaum and Wirth 1997). The Air Quality Index (IAQ) is formulated as follow:

$$IAQ = \sum_{i=1}^{i=n} fi$$

Where: *n*: number of lichen species found in a location; *fi* is the recovery coefficient of each species.

The index of atmospheric purity (IAP)

The method of lichen indication of air quality means identifying, collecting, and calculating the Index of atmospheric purity (IAP) (Djekic et al. 2017; Guillaume 2003; LeBlanc and De Sloover 1970; Krick and Loppi 2002). The IAP is formulated as follows:

$$IAP = 1/10 \sum_{n=1}^{i=n} (Qi * fi)$$

Where: *n*: number of lichen species found in a location; *Qi* is the ecological index of *i* species (the average number of species that coexist with each species); *fi* is the recovery coefficient of each species.

Statistical analysis

Principal component analysis (PCA) was carried out to examine the relationships between the indicators used (H', IAP and IAQ) and air pollution in the study area. UPGMA analysis (Unweighted pair group method with arithmetic mean) was performed on the original variables using Manhattan distance to obtain hierarchical associations of populations. The statistical analyzes were carried out using the STATISTICA 10 software.

RESULTS AND DISCUSSION

The sampling of epiphytic lichens from 60 urban stations in the Setif region recorded 56 lichen species (Table S1). These species belong to 29 genera grouped into 19 lichenic families. The Lecanoraceae family was the richest in diversity, with ten species of lichens, followed by Parmeliaceae (eight species) and Teloschistaceae with seven species (Figure 2). The genus *Lecanora* was the richest with ten lichenic species, while the genera *Arthonia*, *Pertusaria*, *Ochrolechia* and *Xanthoria*) were represented with two species, while 19 genera recorded in the region were represented by a single species.

Heterogeneity in biological richness and abundance among stations studied was observed. The geographical distribution of lichenic species in the study area showed that *Xanthoria parietina* was the common species in the Setif region. It was present in the 60 stations, followed by three species (*Physcia adscendens*, *Physcia aipolia* and *Caloplaca cerina*) (Figure 3a). A sampling of lichens in the study area showed that the most abundant morphological types were crustaceans with 30 species, followed by foliose with 22 species, while fruticose were characterized by two species only; squamuloses and lepers, with one species each, were weakly represented (Figure 3b).

The calculation of the Shannon index (H') allowed us to distinguish variability in the biodiversity of the region with an average of 3.16 ± 1.64 and a significant coefficient of variation (51.93 %) (Table 2). The highest value of the index (H') was noted in Babor municipality (8.07), while the lowest value of the index (H'= 1.24) was recorded in El-Eulma urban area.

The Atmospheric Purity Index (IAP) and Air Quality Index (IAQ) facilitated the estimation of air pollution in the study area. The index (IAQ) showed significant variation across the study region with a mean of 27 ± 16 and a CV of 60.5% (Table 2). The lowest IAQ values were recorded at El-Eulma and Setif stations, indicating poor air quality. On the other hand, the stations with high IAQ values were those of Babor, Bousselam, Oued Bared, Ain Sabt and Beni Chebana, indicating good air quality in these stations.

The IAP revealed the presence of five pollution zones in the Setif region (the localities were grouped into five zones, according to the LeBlanc and Sloover scale (1970)). The majority of localities belong to zone-5 (red), where the pollution was very high. The Municipality of Babor, located in the north of Setif region, was the least polluted locality with cleaner air.

In order to identify the groups of homogeneous stations in the region of Setif based on the different levels of air quality, principal component analysis (PCA) of the 60 municipalities was carried out based on the coupling of bioindication indices (IAP, IAQ) and the biodiversity indices (H', LR and LA). The indices used for the various stations sampled reveal significant variability (Figure 4).

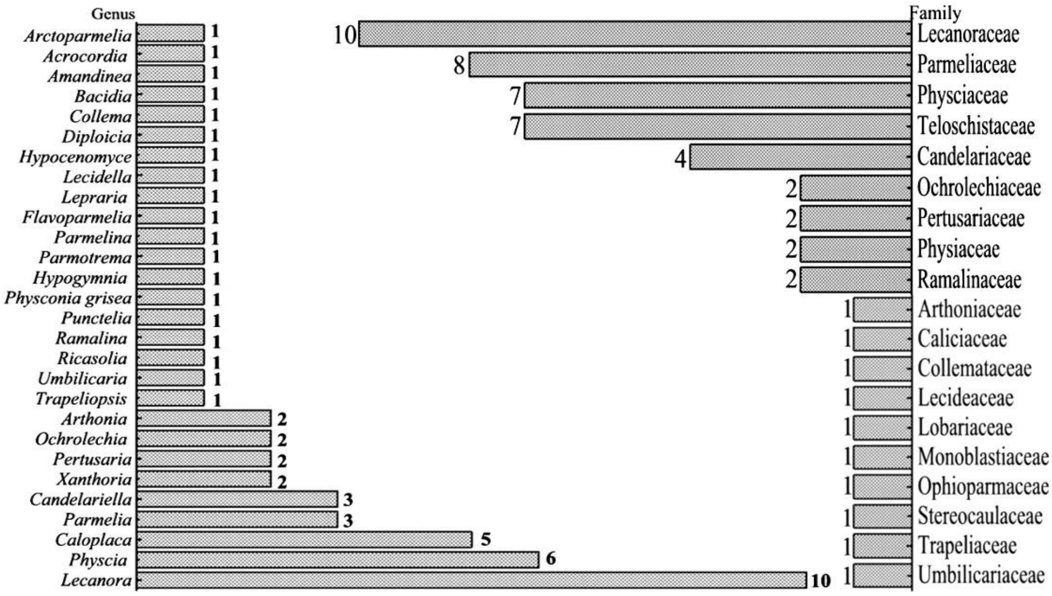

Figure 2. Lichen diversity of Setif region, Algeria based on genera and families

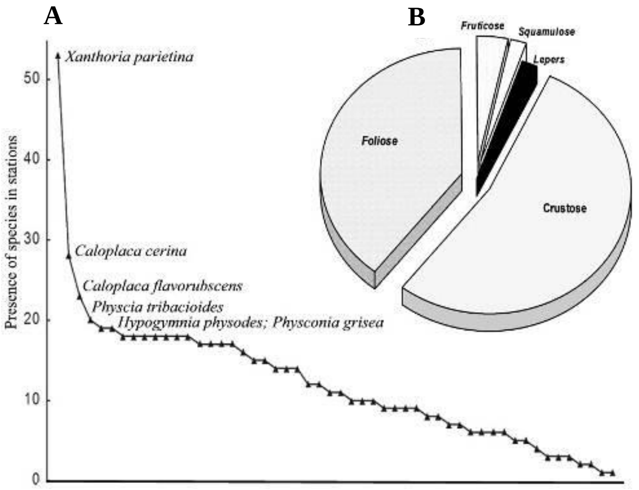

Figure 3. Lichen diversity based on: A. Species abundance; B. Proportion of morphologic types

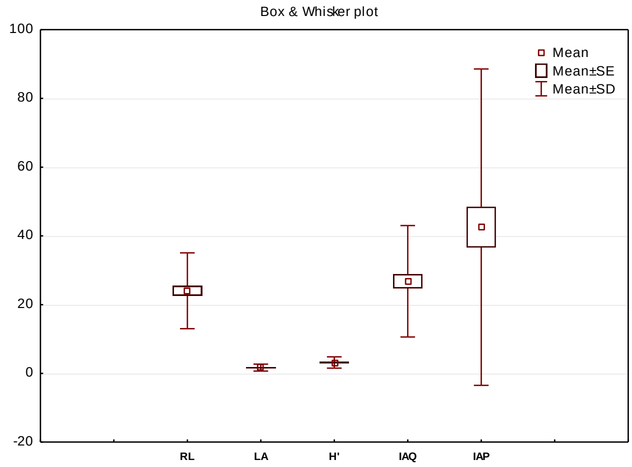

Figure 4. Variability of the ecological and biological indicators of the sampled stations in Setif region, Algeria

Table 2. Main ecological and biological indicators of the sampled stations in Setif region, Algeria

Localities	LR	LA	H'	IAQ	IAP	LP	Localities	LR	LA	H'	IAQ	IAP	LP
Babor	33	4.25	8.07	68	218	Very	Ain Arnet	13	1.07	2.55	17	21	High
Ain Sabt	30	3.19	6.76	51	148	low	Mezloug	12	1.12	2.46	18	20	
Beni Chebana	15	3.21	4.80	51	144		Tachouda	12	1.03	2.38	17	18	
Oued Bared	23	3.98	5.90	64	140		Djemila	10	1.19	2.34	19	17	
Beni Ourthilane	22	3.81	6.09	61	128		Tella	10	1.18	2.17	19	17	
Serdje Ghoule	27	3.05	6.00	49	127		Taya	11	1.15	2.24	18	16	
Bousselam	27	4.23	6.95	68	105		Ouldja	11	1.00	2.34	16	16	
Beni Aziz	26	2.58	5.69	41	103		Rasfa	11	0.95	2.18	15	15	
Beni Mouhli	20	3.28	5.35	53	100		Baida Bordj	10	1.04	2.16	17	15	
Ait Tizi	22	2.93	5.74	47	98		Saleh Bey	9	1.14	1.88	18	15	Very
Maouklane	21	2.39	4.73	38	77		Bellaa	10	0.89	2.14	14	13	high
Bougaa	20	2.39	4.74	38	73		Ouled Saber	10	0.89	1.88	14	13	
Bounadas	16	3.02	4.67	48	72		Ouled Si Ahmed	10	0.86	2.18	14	12	
Guenzet	15	3.19	4.65	51	72		Ain Azel	9	0.96	2.08	15	12	
Hamam Gergour	21	2.16	4.55	35	69		Bazer Sakhra	10	0.81	2.15	13	12	
Draa Kebila	16	2.46	4.25	39	59	Low	Guelta Zarga	9	0.90	1.82	14	12	
Ait Naoual Mezada	13	2.71	3.85	43	52		Bir Arch	9	0.88	1.92	14	11	
Ouled Adouane	19	1.52	3.45	24	44	Medium	Bir Haddada	9	0.85	1.92	14	11	
Ain Roua	14	1.82	3.40	29	38		Maouia	8	0.96	1.87	15	11	
Harbil	12	2.03	3.23	33	36		Hamma	8	0.95	1.90	15	11	
Hamam Soukhna	15	1.51	2.59	24	34		Ouled Tabene	9	0.79	1.87	13	10	
Beni Oussine	14	1.63	3.12	26	34		Beni Fouda	9	0.74	1.66	12	10	
Tizi n'Bachar	16	1.41	3.14	23	34		Ain Lahdjer	8	0.84	1.98	13	9	
Ain Abassa	14	1.56	3.08	25	33		Guellel	7	0.93	1.51	15	9	
Dhamcha	15	1.36	2.89	22	30		Amoucha	5	1.33	1.39	21	8	
Tala Ifacene	11	1.88	3.18	30	30	High	Kasr Abtal	8	0.70	1.51	11	8	
Ain Lagredg	10	1.67	2.87	27	24		Ain Oulmene	7	0.75	1.79	12	7	
Ain Kebira	14	1.13	2.70	18	24		Guedjel	7	0.74	1.35	12	7	
Ourissia	13	1.17	2.60	19	22		El-Eulma	9	0.49	1.24	8	6	
Boutaleb	12	1.21	2.31	19	21		Setif	6	0.63	1.42	10	5	
Average								14	1.67	3.16	27	43	
SD								6,3	1.01	1.64	16	46	
RSD								46	60.50	51.93	61	108	
Min.								5	0.49	1.24	8	5	
Max.								33	4.25	8.07	68	218	

Note: LR: Lichen richness; LA: Lichen abundance; H': Shannon index; IAQ: Air quality index; IAP: Air purity index; PL: Pollution level (LeBlanc et Sloover 1970)

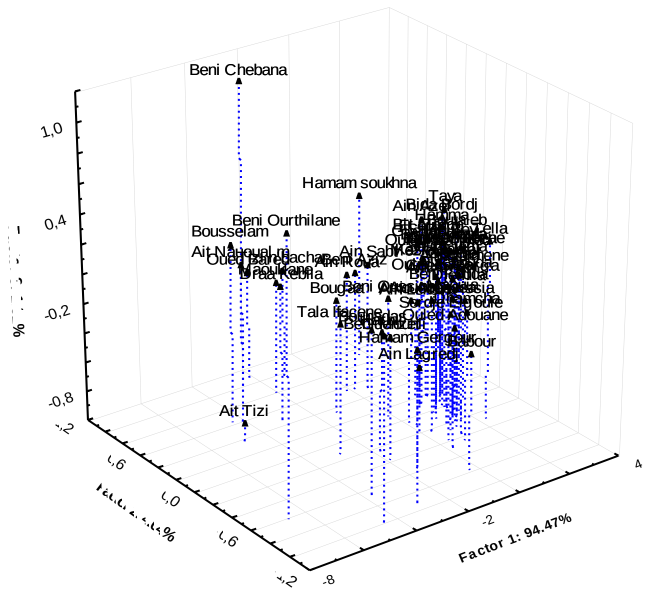

Figure 5. Spatial projection of locations based on the first three axes from the PCA

The Atmospheric Purity Index (IAP) showed more variability across stations, followed by the Air Quality Index (IAQ) and the Specific Diversity Index (RL). We notice that the other indices, lichen abundance index (LA) and Shannon index (H') showed slight variations.

The Principal Component Analysis based on the ecological and biological indicators did not allow good separation of the sampled stations into homogeneous groups (Figure 5). Nonetheless, two stations (Beni Chebana and Ait Tizi) stood out since these two stations were rich in lichenic species, and the pollution was very low.

UPGMA analysis using Manhattan distances was carried out to group the sampled stations into a homogeneous set. This analysis confirms the PCA results, and shows the heterogeneity of the stations by separating them into two distinct groups (Figure 6).

The first group is represented by the rural mountain resort of Babor. This station had a significant lichen diversity with 33 species of lichens, equating to 58.92% total lichen species recorded in this study. At the same time, the second group is divided into two branches. The municipalities of Amoucha, El-Eulma, Guedjel, Guellel, Ain-Oulmen, Kasr Abtal and Setif represent the first branch; these stations showed a very low lichen richness between five and nine species. The second branch groups the stations, which seemed to have a moderately rich lichen diversity.

We observed erosion of the lichen flora in most of the urban stations studied, suggesting a strong impact of the sources of air pollution, in particular in stations with a strong human impact, such as Setif and El-Eulma. The highest atmospheric purity index values were observed in the localities of Babor, Ain Sebt, Beni Chebana, Serdj Ghoul, Oued Bared, Beni Ouerthilene; these stations are located in the north of the region with high humidity, a low population density, with almost non-existent industrial activities and low road traffic. The IAP values allowed us to group the localities studied into five categories with different levels of air pollution (Figure 7).

Category 1 (Very high): 35% of the municipalities located in the center and south of the study region had very poor air quality. Mainly were urban sites located in old city centers and near industrial facilities (chemical industries; pharmaceutical industries, construction materials industries) such as Setif, El-Eulma, Gedjel and Amoucha), or close to business areas mining (e.g., Kharzet Youcef mine in Ain Azel), quarries (e.g., Ain Lehdjar, Guelel) or near cultivated fields (e.g., Ouled Saber, Maaouia and Kasr Abtal).

Category 2 (High): poor air quality. This category covered 23% of the municipalities in the study area. Mainly communities are located near metallurgical industry and cement factories like Ain Kebira.

Category 3 (Medium): 13% of municipalities in the study region, dispersed in rural sites with average air quality.

Category 4 (Low): good air quality, 3% of the localities studied, located in green areas (e.g., Ait Naoual M, Draa Kbilaa).

Category 5 (Very low): very good air quality, 25% of localities, located in mountainous areas, mainly located to the north of the study region (Babor, Oued Bared, Serdj Ghoul, Ain Sebt, Beni Aziz, Bousselem, Bouandes, Beni Chebana and Beni Mouhli).

The IAQ evaluated for the Setif municipalities allowed us to draw up the map of the air quality of the region (Figure 7). Setif municipalities were characterized by five categories of air quality.

Category 1 (Very high): the municipalities, such as Setif, El-Eulma, Beni Fouda, Geudjel, Ain Oulmen and Kasr Abtal, had very poor air quality due to very high pollution. These localities are characterized by strong anthropogenic activities, contributing to the elimination of cortical lichen.

Category 2 (High): poor air quality for the majority of municipalities in the region.

Category 3 (Moderate): average air quality, low pollution. Cortical lichens are poorly represented.

Category 4 (Weak): good air quality.

Category 5 (Very weak): very good air quality, low air pollution, abundance of lichen flora on trees.

Discussion

Lichens are very sensitive to air pollutants; even in the presence of a small amount of toxic substance, their growth will be affected and may result in death (Contardo et al. 2021; Loppi 2014; Salahudin et al. 2013; Van der Wat and Forbes 2015). There was a very heterogeneous distribution of epiphytic lichens across municipalities of the Setif region. This result is due to the influence of ecological factors that play an important role in the diversity of lichens (Dron et al. 2016; Jayalal et al. 2016; Khastini et al. 2019; Munzi et al. 2012; Ochoa-Jimenez et al. 2015), and probably to the action of the atmospheric pollution which is raging in the region). Road traffic is the main factor contributing to the increase in gas levels in the region, since SO_2 and NO_x are mainly released by motor vehicles compared to other sources such as industrial and agricultural activities (Firdous et al. 2017; Marmor and Randlane 2007).

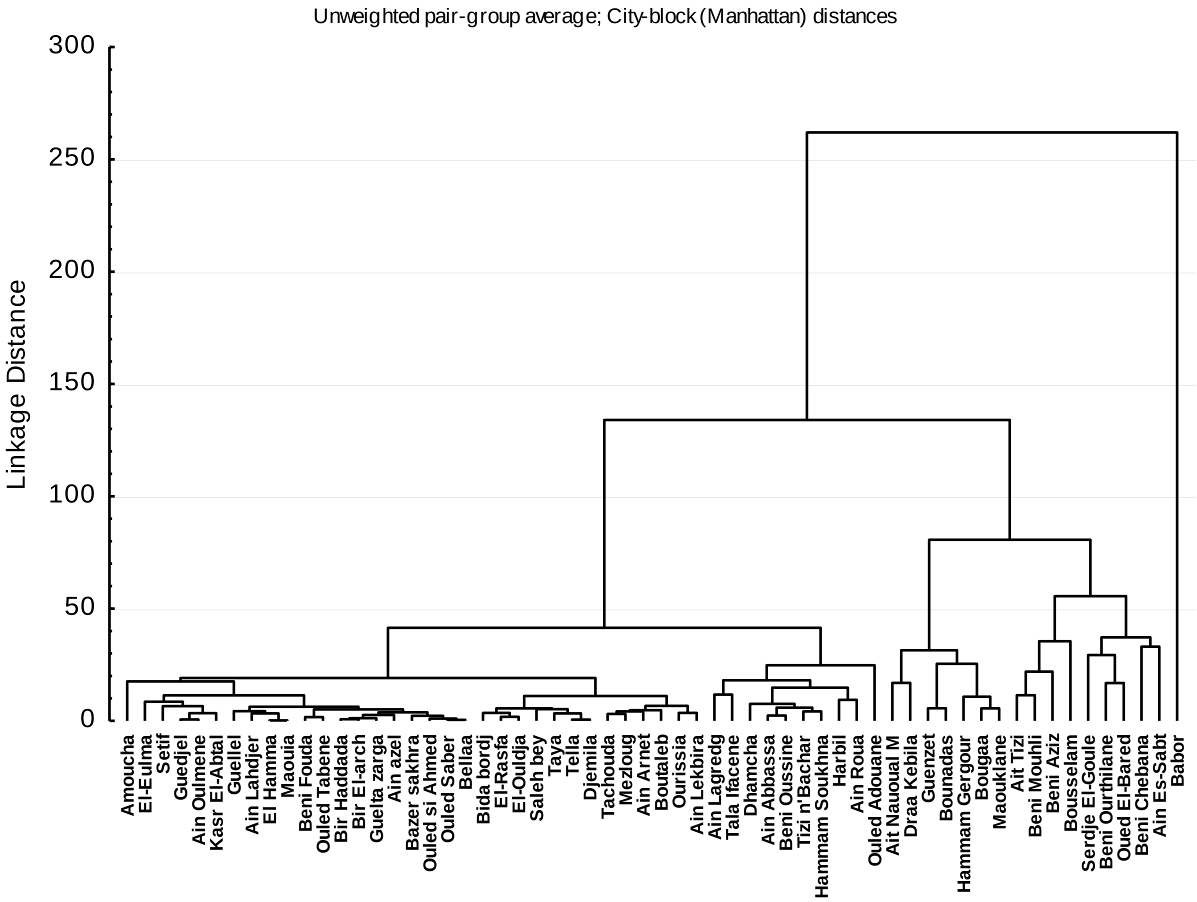

Figure 6. UPGMA clustering based on the lichens' abundance

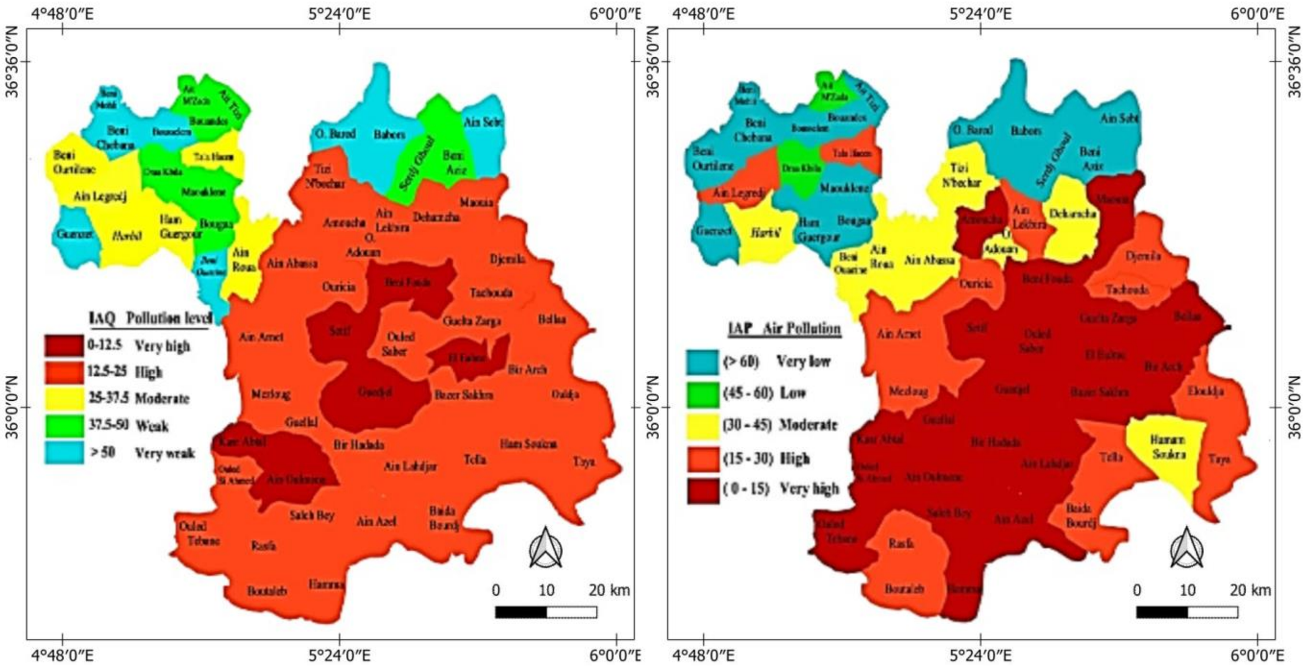

Figure 7. Map of air pollution level in Setif region based on Air Quality Index (IAQ) and Atmospheric Purity Index (IAP)

The values of the indices (IAP and IAQ) based on the diversity and frequency of lichens showed low values, corresponding to low lichen diversity. This is usually associated with air pollution by phytotoxic gases, mainly sulfur dioxide and nitrogen dioxide (Sudirman and Koesmaryono 2015). Highly urbanized municipalities (Setif, El-Eulma, Guedjel, Ain Oulmene, Amoucha; Guellel, Kasr Abtal, Ain Lahdjer and Ain Azel) showed strong air alteration with IAP values ranging from five to 12 and IAQ from 10 to 15. The stations in these municipalities were affected by commercial areas, industrial facilities, quarries, mining, as well as roads with intense road traffic density, causing the epiphytic vegetation to regress (Kar et al. 2014; Khastini et al. 2019; Kitoko et al. 2020; Mcmullin et al. 2017; Sett and Kundu 2016). Studies in the Setif region on the bioaccumulation of metallic trace elements showed a close relationship between high levels of heavy metal pollution and the volume of road traffic (Belguidoum et al. 2020; Koucim et al. 2021).

The same findings have been observed by Koch et al. (2016) in Brazil and Fatima et al. (2019) in Bourdj Bou Arriridj, Algeria, confirming that changes in lichen diversity (the composition and vitality of the community) were very significantly linked to air pollution, especially in urban areas with strong anthropization and incorporated the effect of multiple stressors (particles, NOx and Cu). Loppi (2014) stated that monitoring lichens at an ecophysiological level could allow detection of early symptoms of stress, long before indices of the diversity of lichen communities could indicate the presence of air pollution.

Landscape factors (absence of trees, green spaces), and the pollution carried by the wind could affect stations in the south of the study area, such as Hamma and Ouled Tebben. This is because lichens react to the circulation of air masses, limiting the extent of epiphytic species by reducing their frequency of abundance and diversity (Käffer et al. 2011; Neurohr et al. 2013). Lichen diversity is influenced by climatic factors (air humidity), or environmental factors, such as the presence of green spaces (Jayalal et al. 2016). The same results are observed in urban areas in Italy (Giordani 2007) and India (Das et al. 2013). Epiphytic richness indicating good air quality and high atmospheric purity was observed in rural stations in the North (Babor, Ain Sabt, Oued Bared, Bousselam, and Beni Aziz). These municipalities are located far from sources of pollution. Several authors (Agnan et al. 2017; Khastini et al. 2019) have reported the same observations.

The geographic distribution of lichenic species in the study area showed that *X. parietina* was the common species in the Setif region which was recorded in the 60 stations, followed by three species (*P. adscendens*, *P. aipolia* and *C. cerina*). This shows that these species have the ability to adapt to an environment of a high pollution level (Cristofolini et al. 2008). Also reported the abundance of species of the genus *Lecanora*. Similar observations are reported in the literature, according to which *P. adscendens* was present in most of the sites where *X. parietina* was very common (Dron et al. 2016; Gombert et al. 2004; Merabti et al. 2018). The species *Hypogymnia physodes*, *Ramalina farinacea*, *Collema furfuraceum* are considered by some authors to be indicators of good air quality, and their density on the trees suggests low pollution, therefore good air quality (Belguidoum et al. 2021c; Denis et al. 2020). These species might disappear when the air quality deteriorates and vice versa (Agnan 2013; Gramaglia and Dauphin 2017).

In conclusion, 54 species of epiphytic lichens were identified in this study, of which crustose and foliose lichens were the most common in the region. The pollution indicator indices (IAP and IAQ) showed a well-distinguished correlation between them and a significant difference between rural and urban ecosystems, where urban areas with strong anthropization had very high air pollution. Regular monitoring of the environment can give an assessment of the quality of the air we breathe, but the number of automated air quality monitoring stations is woefully inadequate in the urban areas of Setif, which do not have any air quality monitoring stations. Air pollution should receive more attention as it can affect the health of people at risk of developing cancers. The use of epiphytic lichens as a bio-indicator plays an important role in determining the air quality in the various municipalities of Setif. Because of this biomonitoring, we have shown that the majority of municipalities belong to zone 5 (red), where air pollution is very high. In addition, the presence of *Xanthoria parietina* at all sites indicated that it could be used as a reliable pollutant tolerance bio-monitor in these urban ecosystems. Improvement of the public transport system is the most efficient method to tackle vehicular pollution. The proposed Clean Air 2025, action plan in Setif province aims to reduce urban, industrial air pollution, control and maintain air quality at desirable levels.

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Table S1. Epiphytic lichens from 60 urban localities in the Setif region, Algeria

Species	Location																																																										
	Beni Ouartilene	Beni Mohli	Beni Chebana	Bousselem	Ait Naoual M	Bouandes	Ait Tizi	Ain Lagredj	Draa Kebila	Tala Ifacen	Guenzet	Harbil	Maouklene	Ouad Bared	Hamam Guergour	Bougaa	Tizi n'Berber	Babor	Beni Ouassine	Ain Roua	Ain Abassa	Amoucha	Ouled Adouane	Ain Kebira	Serdj Ghoul	Beni Aziz	Ain Sabt	Dhamcha	Maouia	Ain Arnet	Ouricia	Beni Fouda	Djemila	Mezloug	Setif	Ouled Saber	Guelta Zarga	Tachouda	Kasr Abtal	Guellel	Guedjel	ElEulma	Bellaa	Ouled Siahmed	Ain Oulmene	Bir Hadada	Ain Lahdjar	Bazer Sakra	Bir Arch	Oualdja	Ouled Tabane	Rasfa	Salah Bey	Ain Azel	Hamam Soukhna	Boutaleb	Hamma	Baida Bourdj	Tella	Taya
Arthonia radiata	0	0	0	2.8	0	0	0	0	0	0	0	0	0	3.2	0	3.5	0	2	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Arthonia atra	1.3	0	0	0	0	0	0	0	4.3	0	0	0	0	4.2	0	0	0	0.3	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctoparmelia centrifuga	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.8	4.7	0	0	0
Acrocordia gemmata	0	1	0	2	0	0	1	0	1.2	0	0	0	1	2	1	0	0	1.4	1	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	1.2	1	0	1.6	0
Amandinea punctata	0	0	0	1	0	0	0	0	0	0	0	0	1.8	0	0	1.8	0	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Bacidia arceutina	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0.7	0	0.4	2	0	0.3	0	1.1	0.8	0	0	0	0	0	0	0	0.2	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca cerina	3.6	0	4.2	0	0	0	0	0	0	0	0	5	0	3	2.3	2.1	3.1	1	0	0	3.2	2.6	0	1.6	4.5	2.7	0	4.6	0	2	1.6	2.6	1.3	2.1	0	2	2.3	1.6	0	2	0	0	2		2	0	0	0	0	0	0	0	0	2	2.3	2	0	0	0	0
Caloplaca citrina	0	2.8	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	1.4	0	0	0.7	0	0	1.3	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloplaca ferruginea	1.6	0	0	0	3	2.2	0	0	2.5	0	6	0	0	3.7	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0	1.6	0	0	0	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0	0	0
Caloplaca flavorubscens	3	0	0	2.5	0	2.7	3	2.7	3	2.7	0	0	0	0	3	0	1.3	3.4	0	0.3	3.2	0	0	0	3.2	1.8	0.5	0.3	0	0.3	0.3	0	0	0	0	0	0.3	0	0.3	0	0.3	0	0	2	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0.7	0	0.3
Caloplaca viridirufa	1.6	2.5	2.1	3	0	5	2	2.8	2	2	0	0	4.5	0	0	0	0	3.5	0	0	0	0	1.8	0	0	2.8	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Candelariella coralliza	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.3	0	0	0	0	1	0	0	0.3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1.2	1.5	0	0	0	1	0	0	1	1	1	1.5	0	1.5
Candelariella aurella	0	0	0	1	3.2	2.1	2.2	0	0	2.7	0	0	1.8	3.1	1.8	0	0	0	0	0	0	0	0	0	0.8	0	1.5	0	1.7	0	0	0	0	0	1.8	0	1.7	0	0	0	0.7	0	0	1.3	0	0	0	0	0	0	0	2	0	0	0	0	0	2.5	0	0.7
Candiraliella reflexa	0	0	0	0.8	2	1	1	0	0	2.5	0	0	0	0	2	0	0	1.2	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0
Collema furfuraceum	3.1	0	0	0	1	0	2.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploicia canescens	3.2	0	0	0	0	0	0	2.7	0	0	0	0	3.7	0	3.7	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	1.8	0	0	0	0	0	0	0
Hypocenomyce scalaris	0	3.2	0	0	0	0	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0
Lecanora allophana	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora argentata	0	2.3	0	0	0	0	1.8	0	0	0	0	0	0	0	0	1.2	0	1	0	0	0	0	0.8	0	0	1	0	0	0	1.2	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0	0	0	0
Lecanora dispersa	0	0	0	4.7	0	0	0	0	0	0	0	0	0	0	0.7	1.8	1.2	1	1.2	2.2	0	1	0.8	0.5	0.3	0	0	0	0	1.1	0	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0
Lecanora badia	2.7	2	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0.5	1.8	2.8	2	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0.1	0	0	0	5.1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora chlarotera	0	0	0	2.2	0	0	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora conizaeoides	0	0	0	0	0	0	1.5	0	0	0	3.2	3.2	0	0	0	0	0	2	0	0	0	0	0	0	0	2.7	2.2	1	0	0	1	1.2	0	0.3	0.1	0	0	0.6	1	0	0	0.3	0	0	2.3	0.5	0	0	0	0	0	0.8	0	0	0	0	0	0	0.5	0
Lecanora gangaleoides	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora hagenii	0	0	0	0.9	0	0	0	0	0	0	0	0.6	0	0	0	0	0	1.8	0	0	0	0	0	0.8	0.7	0.9	2.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		2.5	0	0	0	0	0
Lecanora muralis	3	0	2.3	2.8	0	0	2.5	0	0	0	2.3	0	0	0	3	2.3	0	0.8	0	4.5	0	0	0.6	1.5	0	0.2	0	3	0	0	3	0	0	0	0	0	0	1.1	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.5	0	0	0	0
Lecanora strobilina	1	0	3	2	0	0	2	0	0	0	1	1	0	0	2	2	0	3.1	0	3	0	0	0	0	0	0	2	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1.8	1	0	0	0	0
Lecidella elaeochroma	0	0	0	0	4.7	6	0	0	0	0	0	0	0	7.7	0	0	0	0	0	0	1.2	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	1.3	1.8	0.5	0	0	0	0	0	0	0.7	0	0	0.5	0	0
Lepraria incana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochrolechia arborea	5.5	0	3.2	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochrolechia parella	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.7	2	0	1.2	0	0	2.2	0	1.1	0	4.8	0	0	0.1	0.7	0	0.1	0	0	3	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flavoparmelia caperata	0	2.5	0	0	0	2.8	0.8	0	0	0	0	0	0	0	0	2.3	0.3	0	3.2	0	1.8	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0.2	0	0	0	0	0	3	1.8	0	0	0	0	0.3	0.3	0	0	0	0	0	1	0	0	0	0
Parmelia saxatilis	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.3	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	4.5	0	0	0	0	0	0	0	0	0.8	0	0	0.7	0	1.3	0	0	0	0	0	2	0	1.2	0
Parmelina pastillifera	0	2.8	5.5	0	4.3	0	2.7	0	1.7	0	5.5	0	1.3	0	0	1.2	0	0	0	0.2	0	0	0	1.1	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	0.3	1.8	0.5	0	0	0	1.2	0	0	0	0	0	2	0	0	0	1.2	0	0
Parmelia sulcata	3	0	2.3	2.8	0	0	2.5	0	0	0	2.3	0	0	0	0	2.3	0	0.8	0	4.5	0	0	0.6	1.5	0	0.2	0	3	0	0	3	0	0	0	0	0	0	1.1	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.5	0	0	0	0
Parmelia revoluta	2.7	2	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0.5	1.8	0	2	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0.1	0	0	0	5.1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema perlatum	0	1.9	0	0	0	0	0	0	0	0	1.9	0	0	0	0	1.9	0.3	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Pertusaria hymenia	0	1	0	0	0	0	0	0	0	0	1.2	0	0	0	0	1	0.2	2.8	0	0	0	0	0.8	0	0	0	0	0	0	0
Pertusaria flavida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0
Physcia adscendens	1.2	2	2.2	1.1	0	2.1	2	0	1	2	0	1	1.3	1	0	0	2.1	1	0	0	0	2	1	2.2	1	0	0	1	1.6	0.8
Hypogymnia physodes	2.2	6.2	2.2	5	0	0	0	0	0	0	2.2	2.2	3	0	0	0	0	0	4.2	2.2	0	0	0	0	0	0	0	1.1	0	0
Physcia stellaris	1.3	5	0	0	0	0	3.2	2.8	2.7	0	0	0	0	0	0	0	0.8	2.2	0	0	0.5	0	0	1.1	0.3	0	0	0	0	0.8
Physcia tenella	0	0	0	0	0	2.5	0	0	2.7	0	0	0	0	0	0	0	1	0	0	0	3.3	0	0	3.3	0	0	0	0	0	1
Physcia caesia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	1.1	2.6	0	0	0	0	0
Physcia sciastra	5.1	0	5.8	4.7	5.3	3.1	0	3.2	4.7	3.2	5.8	3.8	2	5.7	0	0	0	1.6	0	2.2	0	5.6	0	0.3	0	0	2	0	0	0
Physconia grisea	0	0.8	2	0	3.7	2.3	2.5	2	2	0	2	2	0	3	0	0	0	0	0.3	0	0.3	0	0	0	1.1	0	0	0	0	0
Physcia tribacioides	0	2.8	2.8	1.5	2.7	4.7	0	4.7	2.2	4.7	0	0	2.7	0	2.7	5	0	0	3	0	0	0	0.8	0	0	2.2	0	0	0	0
Punctelia subrudecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramalina farinacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ricasolia amplissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0.3	0	0	0	0	0	1.8	0	0	0	0	1
Umbilicaria polyphylla	3.2	0	0	2	0	0	2.8	0	1.5	0	2.8	2.8	0	0	1.3	0	0	0	0	1.2	2.2	0	0.3	0	0.8	1	0.2	0	0	0
Trapeliopsis flexuosa	2.6	0	0	0	0	6	0	1.5	0	0	0	0	2	0	2	3	0	0	0	0	0	0	1.5	2.5	0	0	4	1.8	4	0
Xanthoria parietina	7.8	7.3	6.2	7.7	7.8	2.8	2.8	3.3	5.8	4.8	6.2	5.2	4	10	0	2.2	3.2	4.6	3.3	3.2	2.5	10	3.3	3.1	3.3	0	2.5	0	3.3	3.1
Xanthoria polycarpa	1.2	0	4.7	3	2.8	0	0	0	1	2.8	4.7	4.7	0.7	0	0.7	0	1	8	0	0	0	0	4.8	3.1	3.3	0	0	0	0	0
Number of species	20	17	12	23	11	13	19	10	14	8	14	10	17	10	18	19	14	28	12	12	13	4	17	15	16	13	10	12	4	12
IAP	112	76	51	84	41	52	75	24	48	36	65	27	51	41	52	67	24	163	25	30	23	19	22	24	31	19	19	19	9.7	16
IAQ	59	47	46	62	41	43	42	27	37	25	50	31	32	46	31	37	18	60	23	27	28	6	36	33	46	23	173	21	29	18

Pertusaria hymenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0.8	0	0	0	0	0
Pertusaria flavida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia adscendens	1	0	0.8	2	1.2	0	0	0	1	0.9	0	1	2	0.9	0	1.2	0.8	1.7	0	0	0	0	0	1.2	0	1.3	1.8	0	0	1.5
Hypogymnia physodes	1.7	0	0	0	1.7	0	0	0	0.2	0.5	0	0	1.2	2	0	0	0	0	0	0	0	0	1.3	2	0	0	0	0	0	1.3
Physcia stellaris	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	2.3	0	0.5	0	0	0.3	0	0	0	0	0	0	0	0
Physcia tenella	0	0	2.3	0	0	4.6	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia caesia	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	4.5	0	0	0	0.7	0	0	0	0	0
Physcia sciastra	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physconia grisea	0	0.2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1.5	0	0.5	0	1.3	1.5
Physcia tribacioides	0	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5	2.5	0	0	0	1.5	0	0	2	2	0	0
Punctelia subrudecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	1.5	0	0	0	0	0	0	0	0	0
Ramalina farinacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ricasolia amplissima	0	0	0	1.1	0	0	0	0	0	0		0.5	0	1.3	0.3	3.8	0	0	0	0	0	3.8	6.8	3	4.8	3.3	0	2	4.3	4
Umbilicaria polyphylla	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.7	2	0	0	0	0	0	0	0	0	0	0	0	0
Trapeliopsis flexuosa	1.8	2.7	1	0	0	0	0	0.8	0.8	0	0	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	0	0	0
Xanthoria parietina	0	2	2.5	1.6	1.1	0	0	2.3	0	0.6	5.2	3	1	2	2.8	3.5	2.7	1.7	3.7	3	0	0.5	0	0.7	1.5	3.7	0	3.7	2	3
Xanthoria polycarpa	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Number of species	11	8	9	10	4	8	7	8	6	6	7	9	9	8	5	8	6	8	5	6	5	7	4	7	14	11	6	8	7	7
IAP	17	11	18	15	4.7	11	12	12	8.3	14	12	7.4	12	12	8.4	12	11	10	8.7	8.8	9.3	10	12	12	21	18	11	14	14	12
IAQ	17	8	15	14	2	8	73	9	5	7	7	6	10	8	4	9	5	7	5	5	4	6	4	7	30	18	6	10	10	8