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Araştırma Makalesi

Lichen Bioindication in the Karaburun Peninsula (İzmir, Turkey)

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Abstract

An air quality study using the IAP method has been carried out in the Karaburun Peninsula. The survey area was divided into 91 units, which were analysed for the frequency of epiphytic lichens on olive trees (*Olea europaea*). IAP values ranged between 0-39.75 and they were classified into nine categories to produce an air quality map. The seashore was recognized as free of epiphytic lichens substantially because of the maritime effect. Finally, availability of olives as phorophyte in bioindication studies was discussed and a list of 16 indicator species has been suggested for the study area.

Keywords: Airborne salinity, bioindication, Index of atmospheric purity (IAP), epiphytic lichens, mapping, Turkey

Karaburun Yarımadası'nda (İzmir, Türkiye) Liken Biyoindikasyonu

Özet

IAP yöntemi uygulanarak Karaburun Yarımadası'ndaki hava kalitesi belirlenmiştir. Çalışma alanı 91 üniteye ayrılmış ve zeytin ağaçları (*Olea europaea*) üzerinde yaşayan epifitik likenlerin frekansı analiz edilmiştir. IAP değerleri 0 ile 39.75 arasında değişmiştir ve bu değerler, hava kalitesi haritası oluşturmak için dokuz kategoriye ayrılmıştır. Sahil bölgesinde, denizsel etki nedeniyle epifitik liken bulunmamıştır. Son olarak, zeytin ağacının biyoindikasyon çalışmaları sırasında forofit olarak kullanımı tartışılmış ve araştırma alanı için 16 indikatör türden oluşan bir liste önerilmiştir.

Anahtar kelimeler: Atmosferik temizlik indisi (IAP), atmosferik tuzluluk, biyoindikasyon, epifitik likenler, haritalama, Türkiye

Introduction

The Index of Atmospheric Purity (IAP) gives an evaluation of the level of atmospheric pollution and environmental stress. This method is based on the frequency and the tolerance of lichens presented in each station at the area under study (Asta et al. 2002 a, b; Conti & Cecchetti 2001; Loppi & Nascimbene 1998; VDI 1995). IAP method supplies information on the long-term effects of air pollutants, eutrophication, anthropization and climatic changes on sensitive organisms (Asta et al. 2002 a). The first and only study in Turkey based on IAP method was performed by Sommerfeldt & John (2001). Other bioindication studies in Turkey were established in Bilecik (Özdemir 1992), Bursa (Öztürk et al. 1997), Eskişehir (Türe 1993), İzmir (John 1989) and Trabzon (Yazıcı & Aslan 2006), where the centres of cities were divided according to Sernander (1926) into desert zone, struggle zone and normal zone.

Compared with other air pollutants, such as heavy metals, radionuclides, organic compounds, etc., saline elements have received little attention in lichen biomonitoring studies (Figueira et al. 1995). Although airborne salinity is not viewed as a typical air pollutant, it has a negative effect on lichen distribution (Figueira et al. 1998a). It has since long been recognized that coastal saxicolous lichens form distinct zones of occurrence (Weddell 1875), however the effect on epiphytic lichens on coastal sides is little known (Figueira et al. 1995) and the degree to which sensitivity to sea salts may control the epiphytic lichen communities in coastal to inland Mediterranean is unknown.

In this study, an air quality study using the IAP method of the Association of Engineers Standards in Germany (VDI 1995) has been carried out in the Karaburun Peninsula (İzmir, Turkey) to calculate the highest IAP value for the Mediterranean Turkey. As result, an adjusted exposure scale has been proposed. In addition, the maritime effect on the seashore is discussed.

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Study Area

Karaburun Peninsula (Figure 1) is a part of İzmir province and covers approximately 325 km^2. The eastern, northern and western parts of this territory lie along the Aegean Sea. The population ranges to 35,000 in the tourism season and is less than 10,000 in the winter (Karaburun Municipality 2010), while Gülbahçe, Ildır, Karaburun and Mordoğan are the most populated of the 29 villages in the peninsula. The climate is Mediterranean with a total annual rainfall of 691.0 mm, ranging from 2.0 mm to 154.3 mm monthly; the mean annual temperature is 17.4°C, with a monthly average maximum and minimum of 27.6°C and 8.6°C, respectively. Ground elevation ranges from 0 to 1218 m and is dominated by macchie and olives (*Olea europaea*). Red pine (*Pinus brutia*) is presented scarily.

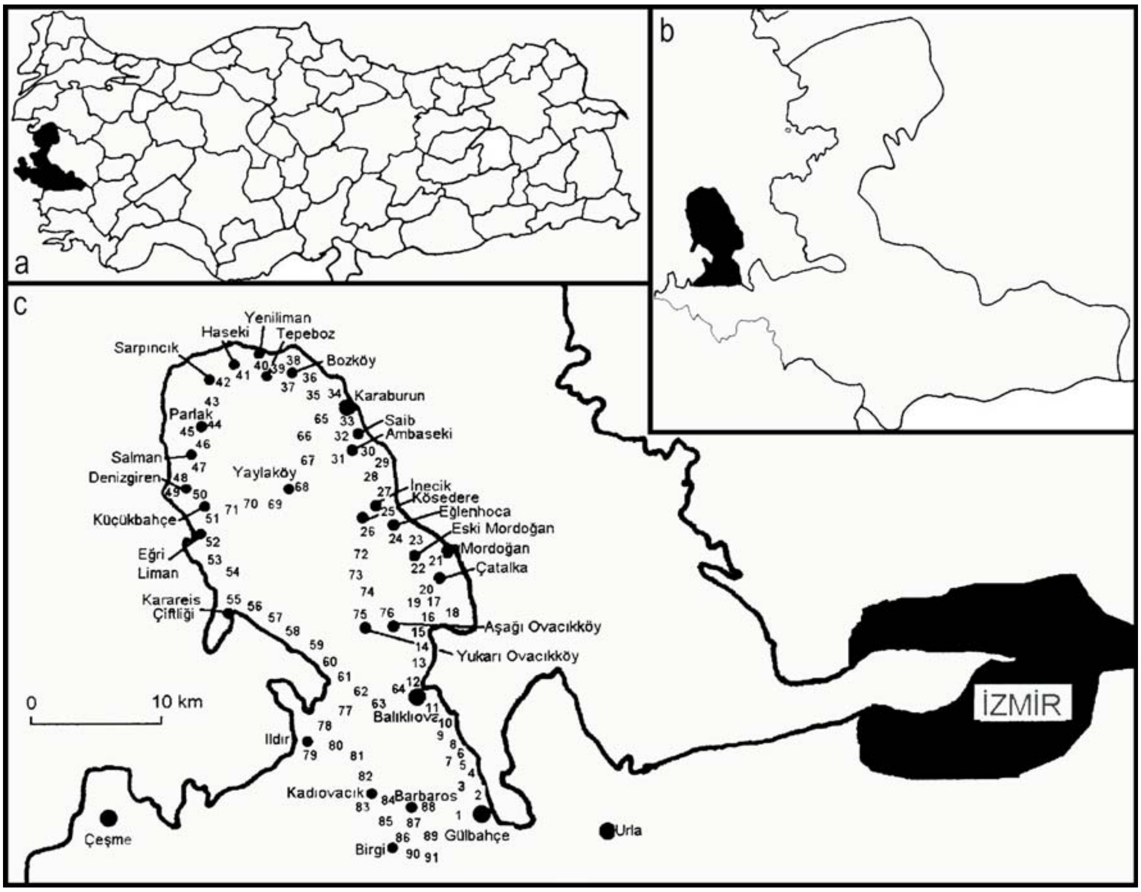

Figure 1: Lichen collection sites in the study area. A. Geographic position of İzmir (black) in Turkey. B. Study areas (black) in İzmir. C. Investigated grid squares. Station numbers (1–91) are given.

The peninsula is a representative area for regions with Mediterranean climate. The limited pollution in the peninsula arises from heating, urbanization, agriculture and traffic. The population is low in the winter and the heating period is short (2–3 months); therefore heating is not a big pollution agent in the region and affects local.

On the other hand, urbanization is intensive in the four big settlings Balıklıova, Ildır, Karaburun and Mordoğan due to summer resort building, but it affects local either. Concerning agriculture; fields are not too much like in other parts of Turkey and mostly olive cultivation is developed.

The main income of inhabitants is cattle breeding. Finally, traffic emission effects are at lowest level because of low traffic impacts.

Material and Methods

Lichen sampling was performed using the Index of Atmospheric Purity (IAP) method (VDI 1995), which permits a quantitative numerical evaluation of atmospheric pollution in terms of the frequency of the epiphytic lichens found in each station. 1 km x 1 km grid squares serves the basis of the mapping, while each grid were selected with a maximum distance of 4 km. A preliminary survey on the availability of suitable trees before deciding on the tree species and size of the sampling units was carried out in order to avoid many units with no or unsuitable trees.

The study area was composed of 91 grid squares; station number of each grid square is given in map (Figure 1). The south of Yaylaköy could not be investigated since it was not accessible due to military area, nor the north of Yaylaköy and the east of Gülbahçe since no appropriate tree were found.

As conditioned in methods based to IAP (Asta et al. 2002a, b; VDI 1995), when selecting suitable olives, free-standing (well-lit) trees with girths of >40 cm and near straight trunks (inclination <10° from vertical) are examined. Trees subject to damage or disturbance from liming/fertiliser, grazing animals etc. or parts with >25% cover of bryophytes or parts with spilted barks are avoided.

Since all sampling was performed in the field, some species presented identification problems that could not be solved without laboratory analysis. When dubious material was found, the lichen was collected and identified later in the laboratory.

Following the VDI guideline (VDI 1995), a sampling grid of 50 × 20 cm, subdivided into 10 units of 10 × 10 cm, was placed on the bark of four olive trees at each station. The grid was kept in place by means of four nails. The frequency (*F*) of each lichen species (number of subplots of the grid in which the species is present; max. frequency = 10) was used to calculate air quality value (LGW):

$$LGW_j = \Sigma F_{ij} / n_j$$

where

i is the number of the individual tree examined in grid square j

j is the number of the examined unit

F_{ij} is the sum of the frequencies of occurrence on tree i in examined unit j

n_j is the number of surveyed trees within examined unit j

Then, the following equation is used to calculate the mean standard deviation of the project:

$$s_p = \sqrt{\Sigma_j \Sigma_i (F_{ij} - LGW_j)^2 / m(n_p-1)}$$

and

the IAP class width = $t_p \times s_p / \sqrt{n_p}$

where

s_p is the mean standard deviation of all examined grid squares for the entire study

n_p is the average number of trees examined per grid square for the entire study

m is the number of grid squares surveyed for the entire study

t_p is the critical value of the Student distribution for n_p-*1* degrees of freedom.

The calculated width of the air quality classes is the basis for the assignment of the air quality values to the corresponding air quality class:

"class 1": $0 <$ IAP < (IAP class width)

"class 2": (IAP class width) < IAP < $2 \times$ (IAP class width)

"class 3": $2 \times$ (IAP class width) < IAP < $3 \times$ (IAP class width)

etc.

For the evaluation, a modified exposure scale is used:

Level A: $0 \leq$ IAP ≤ 8 Very high level of pollution

Level B: $8 <$ IAP ≤ 16 High level of pollution

Level C: $16 <$ IAP ≤ 24 Moderate level of pollution

Level D: $24 <$ IAP ≤ 32 Low level of pollution

Level E: IAP > 32 Very low level of pollution

If the air quality class falls into two exposure categories, the evaluation of exposure is composed of both categories (VDI 1995). At the final, results were converted to an isogram map by interpolating the IAP-classes, while the maximum distance of effect were adjusted to 4 km.

Results

In this study 91 sampling stations were examined. *Pinus brutia* Ten. and *Olea europaea* L. are the trees which have a wide distribution in the study area as well as in Aegean region at low altitudes. The disadvantage of the red pine is that no lichen vegetation develops on them from sea level up to 600 m. However, olive groves were covered with rich lichen vegetation at the same altitude and the preliminary survey showed that olive was the most widespread and suitable phorophyte to use for the lichen survey. Consequently, VDI method (VDI 1995) was applied to epiphytic lichens on olive groves.

The selection of host trees was based on terms and conditions according to the methodologies (Asta et al. 2002a, b; VDI 1995): Trees subject to damage or disturbance from liming/fertiliser, grazing animals etc. or parts with >25% cover of bryophytes or parts with removed barks are avoided and free-standing olives with girths of >40 cm and near straight trunks (inclination <10° from vertical) are recognized as suitable. Some of natural olives have spilt bark or they were inclined more than 10%. The preliminary survey on olives shows that only 3.6% of trees were suitable for bioindication (Figure 2); Asta et al. (2002b) recommend investigating of 4–8 trees. Fortunately the 3.6% is still enough to find four proper trees for examinations.

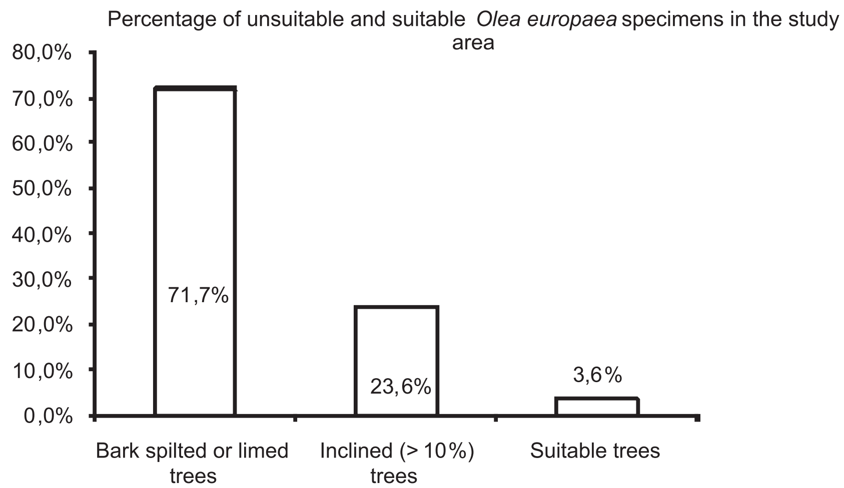

Figure 2: Percentage of unsuitable and suitable *Olea europaea* specimens in the study area (n=960).

Olives with epiphytic lichens were found in 82 stations and no lichen could be recorded in nine grid squares. Six-teen lichen species, mostly belonging to the genera *Caloplaca* and *Lecanora* were found in the study area (Table 1). The most widespread species were *Caloplaca haematites*, *C. holocarpa*, *Lecanora expallens*, *Lecidella elaeochroma*, *Physcia adscendens*, *Rinodina exigua* and *Xanthoria parietina*. By comparison *Lecanora argentata*, *L. chlarotera*, *L. pulicaris*, *Physcia tenella* and *Rinodina capensis* were presented rarely. All identified species are nitrophytic, having their ecological optimum within *Xanthorion* communities.

The Air Quality Values (LGW) and the Index of Atmospheric Purity (IAP) are listed in Table 1. The standard deviation of the study area was calculated as 3.2931 and the class width of each IAP as 5.2393. IAP values vary from 0 to 39.75 per unit

Table 1: List of 16 epiphytic lichen species using in present bioindication study, frequencies of lichen species and IAP classes. Locality nos 2, 4, 6, 10, 13, 27, 29, 38 and 49 are not included in the list, since no lichen was seen on the olives in the grid squares, and therefore have to been excluded from the calculations according to the methodology of VDI (1995).

	Total frequencies in four phorophytes / grid square																			
Grid square no	*Caloplaca cerina* (Ehrh. ex Hedw.) Th. Fr.	*C. cerinella* (Erichsen) Poelt	*C. haematites* (Chaub. ex. St.-Amans) Zwackh.	*C. holocarpa* (Ehrh. ex. Ach.) Wade	*Candelariella reflexa* (Nyl.) Lett.	*C. xanthostigma* (Ach.) Lettau	*Lecanora argentata*(Ach.) Malme	*L. chlarotera* Nyl.	*L. expallens* Ach.	*L. pulicaris* (Pers.) Ach.	*Lecidella elaeochroma* (Ach.) Hazsl.	*Physcia adscendens* (Th. Fr.) H. Olivier	*P. tenella* (Scop.) DC.	*Rinodina capensis* Hampe	*R. exigua* (Ach.) Gray	*Xanthoria parietina* (L.) Th. Fr.	Frequency (F_{ij}) LGW_j=30,192	F_{ij}-LGW_j	$(F_{ij}\text{-}LGWj)^2$	IAP
1	6	1	32	4	6	5	4	1	5	2	30	0	4	4	10	24	34.50	4.31	18.56	IAP8
3	5	2	30	4	4	3	2	4	6	2	28	2	4	2	12	22	33.00	2.81	7.88	IAP8
5	2	0	24	6	6	8	0	2	0	2	32	16	2	0	10	18	32.00	1.81	3.27	IAP8
7	4	1	36	6	6	1	3	1	10	1	27	12	4	2	10	20	36.00	5.81	33.73	IAP8
8	1	0	16	1	8	0	1	0	4	0	2	2	2	0	8	0	11.25	-18.94	358.80	IAP4
9	2	2	34	8	1	4	2	2	4	3	14	14	6	0	18	28	35.50	5.31	28.17	IAP8
11	2	0	28	4	0	2	0	3	12	0	22	1	3	0	11	18	26.50	-3.69	13.63	IAP7
12	6	2	36	4	7	5	1	4	7	2	38	4	2	1	4	36	39.75	9.56	91.35	IAP9
14	3	2	24	6	2	4	3	3	3	3	32	16	10	3	6	18	34.50	4.31	18.56	IAP8
15	1	1	32	11	5	5	0	4	6	1	28	8	2	0	6	26	34.00	3.81	14.50	IAP8
16	3	1	31	5	0	0	1	2	4	1	16	15	0	2	7	20	27.00	-3.19	10.20	IAP7
17	1	0	20	4	4	4	2	2	1	3	36	18	2	0	10	16	30.75	0.56	0.31	IAP7
18	2	0	21	8	5	0	1	1	3	0	28	9	2	0	8	20	27.00	-3.19	10.20	IAP7
19	2	1	38	5	3	2	1	3	1	3	16	8	2	0	14	10	27.25	-2.94	8.66	IAP7
20	2	1	29	3	5	9	4	0	6	0	32	18	6	4	6	11	34.00	3.81	14.50	IAP8
21	4	2	20	9	3	5	4	0	5	3	20	11	2	1	6	6	25.25	-4.94	24.42	IAP6
22	2	1	27	6	1	6	0	0	11	2	21	14	2	3	8	14	29.50	-0.69	0.48	IAP7
23	4	2	24	7	2	5	3	2	7	1	19	7	3	0	18	16	30.00	-0.19	0.04	IAP7
24	0	0	33	6	2	0	4	1	5	1	32	15	7	1	8	22	34.25	4.06	16.47	IAP8
25	5	2	30	5	0	5	0	0	7	1	28	14	0	4	9	20	32.50	2.31	5.33	IAP8
26	2	2	27	6	6	6	2	2	7	3	12	12	0	0	8	24	29.75	-0.44	0.20	IAP7
28	5	0	27	8	2	2	0	2	6	1	28	10	2	2	8	18	30.25	0.056	0.01	IAP7
30	1	2	29	5	2	6	4	1	9	4	28	8	0	2	10	20	32.75	2.57	6.54	IAP8
31	0	1	21	5	5	7	0	1	5	4	29	9	6	0	7	26	31.50	1.31	1.71	IAP8
32	5	0	23	0	5	3	3	1	5	1	25	14	6	0	8	14	28.25	-1.94	3.77	IAP7
33	4	1	25	7	3	4	0	1	4	0	19	12	0	0	10	26	29.00	-1.19	1.42	IAP7
34	2	0	23	8	4	4	0	4	2	4	28	18	0	4	10	24	33.75	3.56	12.67	IAP8
35	2	0	34	2	5	7	1	1	6	2	18	13	0	2	4	14	27.75	-2.44	5.96	IAP7
36	3	0	26	0	4	5	3	0	7	3	30	15	0	3	6	20	31.25	1.06	1.12	IAP7
37	1	2	37	6	5	5	1	4	6	0	16	19	4	0	8	28	35.50	5.31	28.17	IAP8
39	5	0	34	6	2	5	1	0	4	0	16	12	1	1	4	18	27.25	-2.94	8.66	IAP7
40	2	2	34	4	2	0	3	4	6	4	12	13	0	4	10	22	30.50	0.31	0.09	IAP7
41	0	0	26	5	4	5	2	0	5	3	28	11	1	0	9	18	29.25	-0.94	0.89	IAP7
42	5	1	23	5	3	5	1	3	6	2	32	13	0	3	10	17	32.25	2.06	4.24	IAP8
43	5	1	28	5	1	5	1	2	6	4	15	11	2	0	10	18	28.50	-1.69	2.86	IAP7

Table 1 (continues)

Grid square no	Total frequencies in four phorophytes / grid square																Frequency (F_{ij}) LGW_j=30,192	F_{ij}-LGW_j	$(F_{ij}$-$LGWj)^2$	IAP
	Caloplaca cerina	*C. cerinella*	*C. haematites*	*C. holocarpa*	*Candelariella reflexa*	*C. xanthostigma*	*Lecanora argentata*	*L. chlarotera*	*L. expallens*	*L. pulicaris*	*Lecidella elaeochroma*	*Physcia adscendens*	*P. tenella*	*Rinodina capensis*	*R. exigua*	*Xanthoria parietina*				
44	1	2	32	5	6	0	3	1	8	1	23	10	0	1	10	20	30.75	0.56	0.31	IAP7
45	3	2	22	5	6	0	2	0	6	1	22	18	7	2	9	16	30.25	0.06	0.01	IAP7
46	1	1	22	5	5	6	4	0	6	4	28	9	8	3	7	21	32.50	2.31	5.33	IAP8
47	3	0	19	6	5	0	0	2	5	0	28	12	0	2	7	16	26.25	-3.94	15.54	IAP7
48	5	0	25	6	2	7	1	2	4	1	26	16	9	2	9	14	32.25	2.06	4.24	IAP8
50	0	0	29	2	1	7	1	4	7	4	28	14	0	4	4	18	30.75	0.56	0.31	IAP7
51	3	1	26	6	1	1	3	1	4	4	22	5	2	1	5	22	26.75	-3.44	11.85	IAP7
52	4	2	28	6	12	1	1	2	8	2	35	6	0	1	6	24	34.50	4.31	18.56	IAP8
53	4	2	25	5	10	1	1	0	14	4	25	4	8	3	15	24	36.25	6.06	36.70	IAP8
54	1	2	29	2	5	4	0	1	0	4	19	16	8	3	16	20	32.50	2.31	5.33	IAP8
55	0	1	18	3	0	5	3	0	6	4	3	9	2	4	5	14	19.25	-10.94	119.73	IAP5
56	4	2	25	4	7	4	4	4	5	4	19	10	3	3	8	18	31.00	0.81	0.65	IAP7
57	3	1	27	6	5	2	4	4	5	4	23	0	0	0	9	13	26.50	-3.69	13.63	IAP7
58	0	1	38	7	1	0	3	0	6	0	16	14	0	1	15	16	29.50	-0.69	0.48	IAP7
59	1	2	30	9	6	7	1	1	6	1	22	19	0	1	2	19	31.75	1.56	2.43	IAP8
60	4	2	19	4	2	0	1	1	6	1	26	18	0	0	8	15	26.75	-3.44	11.85	IAP7
61	1	1	26	3	3	3	1	3	6	4	35	6	3	2	9	12	29.50	-0.69	0.48	IAP7
62	4	1	24	6	4	0	1	2	5	2	21	18	0	3	12	13	29.00	-1.19	1.42	IAP7
63	3	1	29	7	5	7	4	3	6	2	29	5	0	4	12	14	32.75	2.56	6.54	IAP8
64	3	2	27	6	4	4	1	1	6	1	22	0	2	0	8	12	24.75	-5.44	29.62	IAP6
65	0	2	30	5	6	4	0	3	0	4	33	25	4	1	10	12	34.75	4.56	20.78	IAP8
66	2	2	24	3	1	1	4	1	6	3	32	6	8	0	12	18	30.75	0.56	0.31	IAP7
67	3	1	29	5	0	6	3	2	6	3	26	5	2	1	9	18	29.75	-0.44	0.20	IAP7
68	2	1	30	6	4	3	4	3	6	6	33	4	3	2	8	14	32.25	2.06	4.26	IAP8
69	4	1	38	5	6	3	0	1	0	3	22	17	0	0	8	19	31.75	1.56	2.43	IAP8
70	1	2	34	4	5	1	4	4	1	4	16	6	2	0	10	17	27.75	-2.44	5.96	IAP7
71	2	0	25	5	5	6	1	4	4	1	28	15	4	0	5	16	30.25	0.06	0.01	IAP7
72	4	2	20	5	5	4	3	4	5	4	25	14	3	2	10	13	30.75	0.56	0.31	IAP7
73	3	1	31	7	4	5	1	2	8	2	21	9	5	2	10	12	30.75	0.56	0.31	IAP7
74	3	0	28	6	0	4	4	1	2	1	30	14	0	3	12	12	30.00	-0.19	0.04	IAP7
75	1	0	27	8	5	5	1	1	8	1	23	17	0	1	7	17	30.50	0.31	0.10	IAP7
76	3	0	33	5	6	4	1	1	7	4	11	20	3	0	8	18	31.00	0.81	0.65	IAP7
77	1	2	23	7	3	2	1	4	0	0	30	4	0	0	8	23	27.00	-3.19	10.19	IAP7
78	0	1	23	4	5	3	1	1	5	1	17	0	2	0	9	13	21.25	-8.94	79.96	IAP6
79	4	0	25	4	2	5	0	0	0	1	30	6	0	1	16	12	26.50	-3.69	13.63	IAP7
80	5	2	31	6	2	4	3	1	0	2	30	2	0	2	16	12	29.50	-0.69	0.48	IAP7
81	2	1	32	7	5	6	0	1	0	2	25	11	0	1	14	16	30.75	0.56	0.31	IAP7
82	2	2	24	6	7	1	1	3	7	0	32	6	8	4	7	16	31.50	1.31	1.71	IAP8
83	0	1	18	7	3	4	3	1	14	0	31	10	2	1	14	19	32.00	1.81	3.27	IAP8
84	3	1	31	4	8	7	0	0	10	2	25	0	3	3	6	15	29.50	-0.69	0.48	IAP7
85	0	1	35	5	6	0	0	4	5	0	22	14	3	4	11	13	30.75	0.56	0.31	IAP7
86	1	1	35	8	5	4	1	1	4	3	21	10	0	2	7	19	30.50	0.31	0.10	IAP7
87	5	1	24	6	4	7	1	0	7	0	32	5	0	4	6	16	29.50	-0.69	0.48	IAP7
88	1	2	24	5	4	0	2	4	7	2	23	25	0	0	11	22	33.00	2.81	7.88	IAP8
89	5	1	26	4	0	4	0	2	6	3	28	8	2	4	5	20	29.50	-0.69	0.48	IAP7
90	1	0	24	5	3	4	4	1	4	1	27	16	1	0	6	21	29.50	-0.69	0.48	IAP7
91	2	1	23	13	4	2	3	2	4	3	28	4	0	0	12	16	29.25	-0.94	0,89	IAP7
Σ	51.8	22.0	562.0	111.0	80.3	75.0	35.8	36.3	109.0	42.5	503.0	219	48.5	31.5	186.0	363.0	2475.80	0.00	1198.3	

A modified exposure scale with 0–8–16–24–32 steps were used because of the calculated maximum IAP value (Figure 3).

According to the calculated IAP values, the study area was divided into nine air quality zones (Figure 3): The extremely polluted zone (IAP1 = 0) corresponds to the seashore and it was caused by maritime effect. The very high polluted (0 < IAP2 ≤ 5.2) and the high to very high polluted zones (5.2 < IAP3 ≤ 10.5) are not presented in the study area, while high polluted zone (10.5 < IAP4 ≤ 15.7) is limited only to one locality at the southeast part of the peninsula (at the south of the Balıklıova village), and the moderate to high polluted zone (15.7 < IAP5 ≤ 21.0) is limited only to one locality at the western part of the peninsula (at the north of the Karareis Çiftliği). Only three stations correspond to the low to moderate polluted zone (21.0 < IAP6 ≤26.2). Urbanization and marble mines are the emission sources in units listed above, however, the pollution affects local since the companies are small. The low (26.2 < IAP7 ≤ 31.4) and very low to low polluted (31.4 < IAP8 ≤ 36.7) zones are dominant with 48 and 27 stations, respectively. The very low polluted zone with IAP9 >36.7 is poorly represented, limited only to one station at southeast part of the peninsula (at the north of the Balıklıova village).

An isogram map (Figure 4) was produced by interpolating the IAP-classes. Isograms were not joined for the stations far than 4 km.

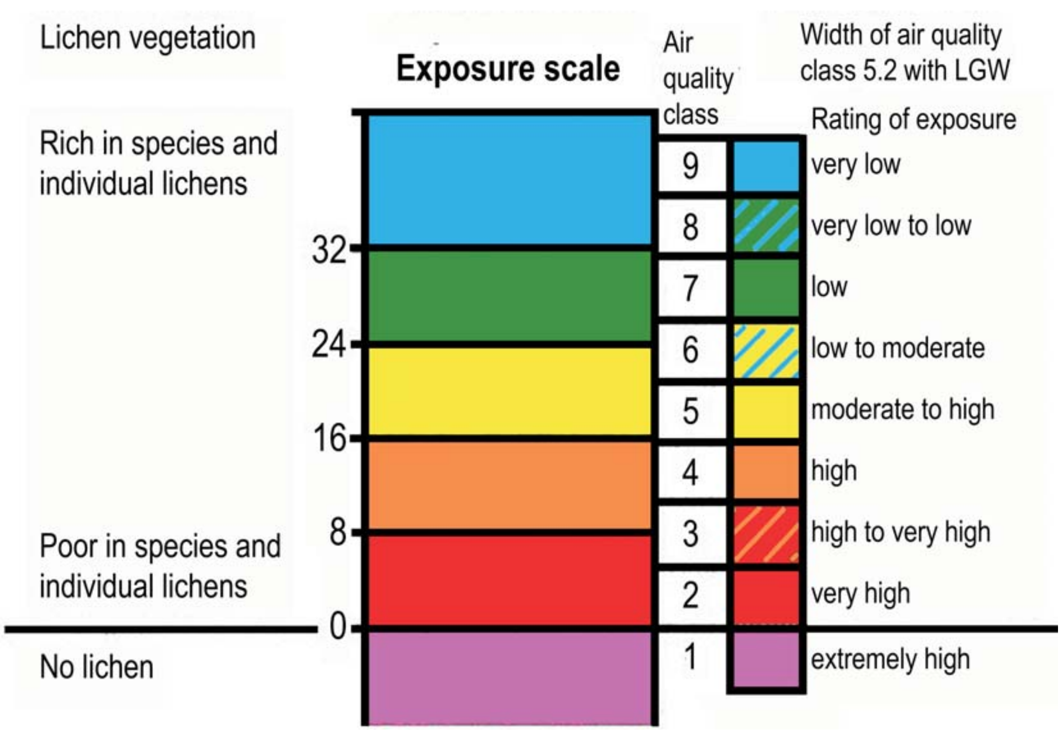

Figure 3: Proposed and applied exposure scale. The width of air quality classes is based on the data of the study area.

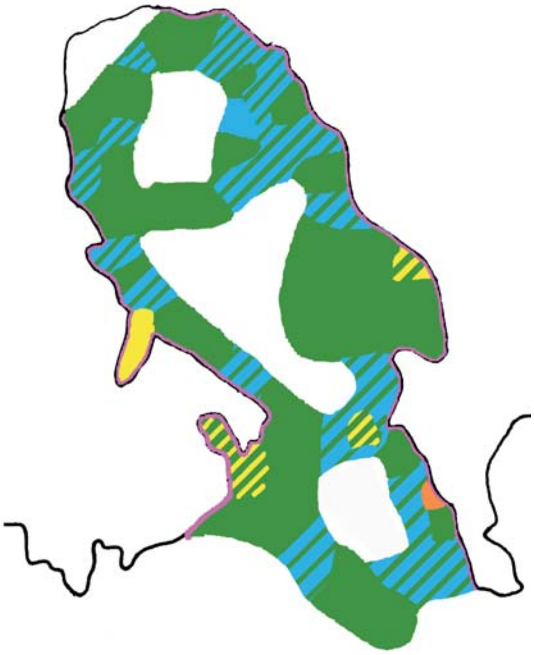

Figure 4: Air quality (isograms) map of Karaburun Peninsula

Discussion

According to Asta et al. (2002a), tree species must be selected after a reconnaissance of the study area. The preliminary survey shows that only two tree species, namely *Pinus brutia* and *Olea europaea*, have a wide distribution in the study area. Unfortunately, no lichen vegetation develops on red pine from sea level up to 600 m and most of our collection site was situated below than 500 m. However, olive groves were covered with rich lichen vegetation at the same altitude. Since only trees of a single species should be selected within a survey (Asta et al. 2002a), only olive was chosen as the host tree.

According to Asta et al. (2002a), in cases where single tree species are not available at the study area, trees with similar properties have to been used, because epiphytic lichen growth strongly depends on bark properties. Therefore, national authorities should prepare lists of trees with similar physicochemical bark properties based on the national tree floras and bioindication studies should not include trees with unknown ecological bark properties (Asta et al. 2002a). Nevertheless, studies concerning bark properties were not established by Turkish authorities. For this reason, this study was correctly applied only on olive grooves.

There are twenty different formulae for IAP calculation (Conti & Cecchetti 2001). Asta & Rolley (1999) reviewed the formula of IAP, where the frequency was ranked from 1 to 5 only, instead of 10 as usually. The VDI (1995) method is based on the calculation of the frequency of species within a sampling ladder of 10 quadrates (each 10 × 10 cm) placed against the trunk. An alternative method of IAP (Nimis et al. 1990), based on the sum of frequencies on 10 quadrates each 15 × 10 cm, has been widely applied in Italy, as summarized in Conti & Cecchetti (2001). Another alternative method (Asta et al. 2002a) bases on twenty 10 × 10 cm quadrate squares, compared with the ten 10 × 10 cm quadrate squares of VDI. Our methodology follows that of the VDI (1995).

Sommerfeldt & John (2001) examined 1092 trees in 330 units according to the guideline of VDI (1995). The IAP values varied from 0 to 36.5, while the highest values were calculated for units situated in western and southern border of the city. These are parts which seem to belong to normal zone in Sernander's system (1926). Unfortunately, these values of such a valuable and informative study are not comfortable for comparison according to Asta et al. (2002 a, b) and VDI (1995), since every phorophyte was used without giving attention to their bark properties.

In Europe, Gombert et al. (2004) has studied the air quality of Grenoble (Northern Alps, France) with IAP and index of human impact (IHI) on 198 units (0.7 × 1 km), in which 345 average lichen relevés were analyzed. As result, the IAP values varied from 5.9 to 71.7 per unit, where frequency of each species in each tree ranked from 0.5 to 5. The IAP values varied between ">20" and "<70" in a lichen bioindication survey of air quality performed based on 153 sampling in the Mr. Amiata geothermal area (Italy) characterized by sub-Mediterranean climate, where the maximum frequency value was set as 10 (Loppi & Nascimbene 1998). In another lichen bioindication survey performed on 193 sampling in the Pisa province (Italy), characterized by temperate climate, the IAP values varied between 0 and ">50", where the maximum frequency value was set as 10 either (Scerbo et al. 2002). The exposure scale provided in Asta et al. (2002a) divides the IAP values from 0 to 20 as "very low", 20 to 40 as "low", 40 to 60 as "moderate", 60 to 80 as "high" and 80 to 120 as "very high". However, this system is based on twenty 10 × 10 cm quadrate squares and maximum frequency value of 20 each tree, compared with the ten 10 × 10 cm quadrate squares of VDI (1995) with maximum frequency value of 10 each tree. The exposure scale of the VDI (1995) groups into five levels: $0 \leq IAP \leq 12.5$ as very high level of pollution, $12.5 < IAP \leq 25$ as high level of pollution, $25 < IAP \leq 37.5$ as moderate level of pollution, $37.5 < IAP \leq 50$ as low level of pollution and $IAP > 50$ as very low level of pollution.

The IAP values of our study vary between 0 and 39.75 per unit in the present study. Application of the exposure scale of Asta et al. (2002a, b), Nimis et al. (1990) and VDI (1995) to the present study is unrealistic, since the scale was proposed for the Central Europe and these values are too high for the East Mediterranean Region. The differences are based on tree biodiversity, lichen biodiversity and climate.

Even if these scales were applied to the present study, less polluted areas would be turned out as polluted zones. For example, station no 12 is a station with the highest IAP value as 39.75; however, this value equals to "low polluted" category according to VDI (1995), and not "extremely low polluted" category as in present study. The second highest IAP value was calculated as 36.25 for the station no 53, though this equals to "moderate polluted" category instead of "extremely low polluted" category. Therefore a regional scale seems to be necessary. In absence of a regional scale, the difference between maximum and minimum IAPs within the survey area should be used to create a scale which detects local pattern of environmental alteration (Asta et al. 2002b). For this reason, a modified exposure scale is proposed here (Figure 3) and it was applied to this study.

Trees in stations close to sea (at least 100 m) were free of lichens. Therefore, the seashore zone was marked as "polluted" in Figure 1. This pollution is not arising from the traditional pollutants. This phenomenon is caused by the maritime effect either to lichens or physicochemical properties of the barks. In the marine boundary layer, the basic mechanism responsible for the production of salt spray is the bursting of air bubbles at the sea surface, as summarized in Figueira et al. (1998b).

Usually, halotolerance were viewed rather on epilithic lichens than epiphytic lichens. However, some results on epiphytic lichens help us to understand the behaviour of lichen communities growing on barks. Only Figueira et al. (1998b), Grube & Blaha (2005) and Nash & Lange (1988) take the epiphytic lichen communities in account.

Nash & Lange (1988) has studied the responses of lichens to salinity on 12 Californian species (10 epiphytic and two epilithic) and they conclude that species that grow near the ocean, such as *Caloplaca coralloides* (Tuck.) Hulting, *Niebla cephalota* (Tuck.) Rundel & Bowler and *Dendrographa minor* Darb. were quite tolerant of sea salt. In contrast, the species restricted to inland sites were either very sensitive or at least moderately sensitive. Grube & Blaha (2005) overviewed halotolerant lichens with focusing on maritime lichens. Among the epilithic and epiphytic specimens examined, six saxicolous maritime species tolerated 1.2 M NaCl; only one epiphytic species, *Niebla homalea* (Ach.) Rundel & Bowler, showed enhanced growth at 0.6 and 1.2 M NaCl. Figueira et al. (1998a) has investigated the effects of deposition saline particles on *Ramalina canariensis* J. Steiner, one of the most halotolerant species among lichens (Figueira et al. 1999), growing on stems of *Pinus pinaster* L. at ca. 800 m from the coast in southern Portugal, where Cl^-, Na^+ and Mg^{+2} may bias the direct indication of atmospheric deposition by lichens. According to these results, *Caloplaca coralloides*, *Dendrographa minor*, *Niebla cephalota*, *N. homalea* and *Ramalina canariensis* are known as halotolerant among epiphytic lichens. None of these species occur in our study area, while no halotolerant species was seen in any tree examined.

The reasons of the effect of elements in coastal regions were discussed in Brown & Di Meo (1972), Figueira et al. (1998a, 1999a, b, c), Nash & Lange (1988) and Pachero et al. (1999): Chloride (Cl^-), sodium (Na^+) and magnesium (Mg^{+2}) are important elements in the definition of a salinity index, and can be interpreted as sea-salt tracers (Figueira et al. 1999c). Significant negative correlation was previously found between the chloride and sodium concentrations of the distance from the coast; higher values were obtained in sites near to the coast and their concentrations declined with increasing distance from the coast, in a logarithmic mode (Brown & Di Meo 1972, Figueira et al. 1999a).

Conclusion

The necessity of application of the IAP methods is rising in Turkey. So far, such a study was performed only in İzmir province (Sommerfeldt & John 2001). However an appropriate exposure scale is not available at least for Mediterranean Turkey. A modified exposure scale is proposed here. Nevertheless, the magnitude of deviation from naturality of this new scale cannot be assessed. Therefore this scale should be refined with forthcoming studies on bioindication.

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