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An Assessment on Bioclimatic Requirements of Endemic *Quercus aucheri* Jaub. et Spach. Communities Spreading South-West Anatolia, Turkey

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Abstract: This study was carried out to determine of bioclimatic tolerance ranges of *Quercus aucheri* Jaub. et Spach. It is an endemic for Turkey and called as Boz pırnal oak in Turkish. In the determination of bioclimatic appropriateness, the methods of Emberger (Q_2; the humidity category, m; the winter variant) De Martonne (LDS: the length of the dry season) and Gaussen (DSWD: the dry season water deficit) were used. According to Emberger's climagram method used by Quézel and Barbéro, the bioclimatic tolerance range of Boz Pırnal oak is remarkably large as it includes up to 8 different types of Mediterranean bioclimate. Therefore, the bioclimatic niche of the Boz Pırnal oak in Turkey is characterized by highly heterogeneous; cool-humid, cool-subhumid, cool-semiarid, temperate-humid, temperate-subhumid, temperate-semiarid, warm-humid and warm-subhumid.

Key words: Bioclimatic requirements, extent of occurrence, Mediterranean bioclimate, *Quercus aucheri* (Boz pırnal oak)

INTRODUCTION

There are 18 *Quercus* species in Turkey and *Quercus aucheri*, called Boz pırnal oak in Turkish, is an endemic for Turkey. Boz pırnal oak is East Mediterranean element and in CD (conservation dependent) group according to the risk categories of IUCN (Ekim *et al*., 2000; IUCN, 2001).

Boz pırnal oak is an evergreen oak species and it can be found in bush or tree (~10 m highness) forms. Its leaves (1-4×1-2.5 cm) are large and elliptic. The upper sides of the leaves are usually unhairy and the lower sides have thin greyish hairs and are covered by a fine wax. Their leaf stalks are too little to see and they have no fruit stalk (Davis, 1982). This species is widely spread on especially hard calcareous bedrock and terra rosa soils in the South-West Anatolian of Turkey (Akman, 1995).

A number of studies have focused on various ecological traits of Boz pırnal oak and its extension areas in Turkey were determined (Tuzlaci, 2004; Makineci, 1998; Tilki and Alptekin, 2005; Sayhan, 1990). Boz Pırnal oak is grown in the near coastal places of South-West Anatolia, between Kuşadası borough and Antalya Province (Fig. 1). In these areas they form community intervals in approximate total of 10-12 k ha.

The latest report on some other oaks out of Boz Pırnal oak live in Turkey belongs to Dufour-Dror and Ertas (2004). They investigated the ecology and some other features of the subspecies of *Quercus ithaburensis*' such as subsp. *macrolepis*, live in Turkey and subsp. *ithaburensis*, live in Israel. They focused on bioclimatic tolerance limits of these taxa.

The purpose of this study was to explain the ecological and the bioclimatic tolerance ranges and the status of the Boz pırnal oak in Turkey which is characterized by a great diversity of Mediterranean bioclimate (Emberger, 1955, 1971a, b; Daget *et al*., 1988). For this aim, Emberger (Q_2, m) De Martonne (LDS) and Gaussen (DSWD) methods were used.

MATERIALS AND METHODS

This study was carried out in between 2007-2008. The Mediterranean bioclimate of a given sub region is defined according to two quantitative criteria. The global humidity of the climate, which is calculated according to the pluviothermic quotient noted Q_2 and the severity of the winter which is a function of temperature (Daget *et al*., 1988).

Emberger's pluviothermic quotient and winter variants: Several researchers analysed thoroughly the origins and the principles of Emberger's pluviothermic quotient and Winter variants and there is therefore no need to detail

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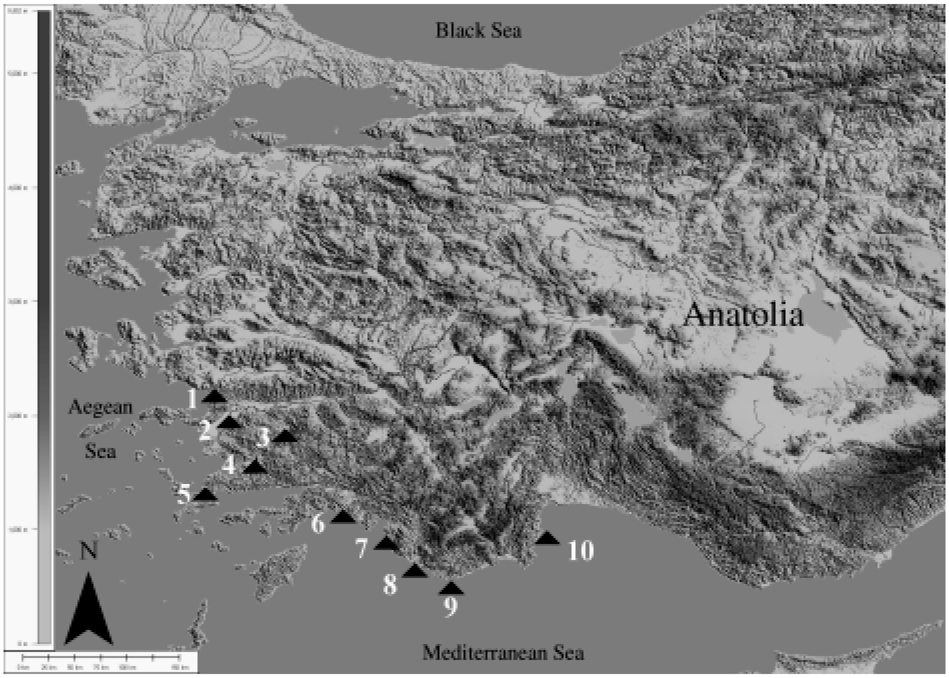

Fig. 1: Extent area of Boz pırnal Oak in Turkey. 1: Karacadağ (Kuşadası), 2: Söke, 3: Çine valley, 4: Milas, 5: Bodrum, 6: Köyceğiz, 7: Fethiye, 8: Kalkan, 9: Kaş and 10: Kemer (The areas of Boz pırnal Oak's communities: ▲)

these aspects again (Daget, 1977a, b, 1984; Nahal, 1981; Daget and David, 1982; Quézel, 1985; Daget *et al*., 1988). However, for reference, the formula of the pluviothermic quotient (Q_2) shall be mentioned:

$$Q_2 = 2000\ P/[(M+m+546.24)\ (M-m)]$$

where, P is the mean annual precipitations in mm, M is the mean of the maxima of the hottest month in°C and m is the mean of the minimal temperature values of the coldest month in °C.

According to the value of the Q_2, up to five categories of humidity could be distinguished (Table 1). Similarly, 5 winter variants, i.e., thermal variants are differentiated according to the values of m (Table 2). The importance of minimum temperatures in defining the distribution of plant species has been pointed out by Larcher (1983) and Woodward (1987).

The climagram: The categories of humidity and the winter variants can be graphically displayed on a climagram (Fig. 2) which enables to represent schematically the bioclimatic tolerance range of any plant species provided its spatial extent is known and relevant climatic data are available. The bioclimatic tolerance range of numerous Mediterranean forest species, conifers and

Table 1: Humidity categories defined according to the values of pluviothermic quotient (Q_2) when m = °C (Quézel and Barbéro, 1985; Daget *et al*., 1988; Barbéro *et al*., 1992)

Humidity category	Q_2
Arid	17-30
Semi-arid	30-57
Sub-humid	57-98
Humid	98-150
Per-humid	>150

The threshold values of Q_2 used to distinguish humidity categories increase as values of m get higher (Fig. 2)

Table 2: Winter variants according to the values of m (Quézel and Barbéro, 1985; Daget *et al*., 1988; Barbéro *et al*., 1992)

Winter variant	m (°C)
Warm	7-10
Temperate	3-7
Cool	0-3
Cold	-3-0
Very cold	-3 to -7

broad-leaved, have been presented on the climagram, e.g., among oak species one can mention *Quercus pubescens* Willd., *Q. cerris* L., *Q. faginea* Lam., *Q. ilex* L., *Q. coccifera* L., *Q. calliprinos* Webb., *Q. suber* L. and *Q. ithaburensis* Decne (Quézel, 1976, 1980; Quézel and Barbéro, 1985; Dufour-Dror and Ertas, 2004).

Referring to the bioclimatic characteristics of the dry season: Duration and severity: The furthest east and north points of study area was Karacadağ (Kuşadası), the furthest west point was Kaş and Far East point was

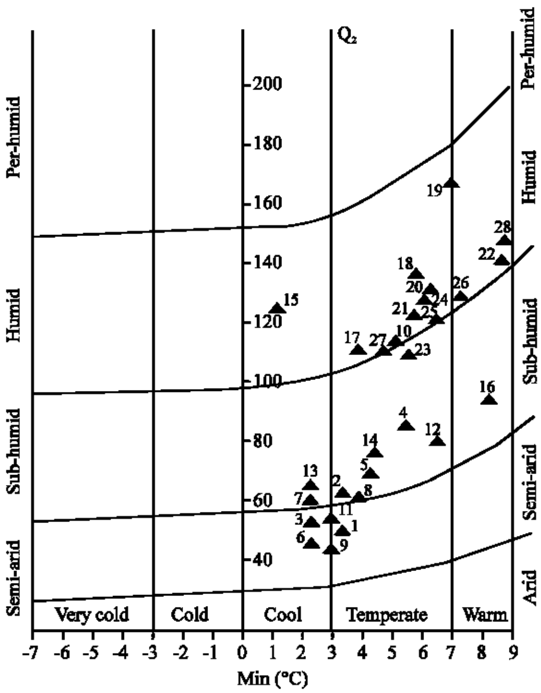

Fig. 2: Emberger's climagram displaying the various types of Mediterranean bioclimates (Quézel and Barbéro, 1985). The climagram based on 10 localities and 28 meteorological stations' records nearby the localities. They present densely in all localities shown in Fig. 1 and ~200 inds ha^{-1}

Kemer. Some researchers argued that Emberger's method failed to account for the different patterns of annual rainfall distribution existing in the Mediterranean (Daget, 1977a, 1984; Nahal, 1981). Indeed the duration and the severity of the summer drought may be very variable within the Mediterranean basin (Dallman, 1998; Blondel and Aronson, 1999). In order to define accurately the bioclimatic tolerance range of Boz pırnal oak, the length of the dry season (LDS) and its severity shall be taken into account.

Duration of the dry season: Monthly drought index formula of De Martonne:

$$I = [P/(t+10)\ 12]$$

The LDS can be calculated according to De Martonne's Emm (1948) method which is considered to be one of the most useful system for characterizing Mediterranean bioclimates (Blondel and Aronson, 1999). According to De Martonne's Formula: I, Monthly drought index (I); p = mm, monthly rainfall amount; t = °C, monthly average temperature. In this formula, if the value is less than 10 it means that this month is arid.

Severity of the dry season: A comprehensive characterization of a dry season requires a quantification of its severity. The severity of drought, as experienced by a plant, relates to the amount of water stored in the soil and depends on the balance between rainfall and water loss in evapotranspiration. Therefore, in order to quantify the severity of the dry season, it is suggested the use of an absolute water deficit during the dry season, the length of which is calculated according to Gaussen's method. The dry season water deficit (DSWD) is expressed in mm and can be calculated as follows:

$$DSWD = p - PET$$

where, p is the monthly rainfall amount (mm) and PET is the monthly potential evapotranspiration (mm).

Among the numerous equations proposed in order to calculate the PET, Turc's appears to be the most appropriate for Mediterranean-climate regions (Lecarpentier, 1975). Penman's and Priestley-Taylor's model are used in areas of low moisture stress while Thornthwaite's method, initially developed for coastal conditions in New Jersey, is more appropriate for calculating PET in temperate regions. The equation for Turc's method is:

$$PET = (Rs+50)\ (0.013n)\ [T/(T+15)]\ [1+((50-RH)/70)] \text{ for } RH<50\%$$

$$PET = (Rs+50)\ (0.013n)\ [T/(T+15)] \text{ for } RH>50\%$$

Where:

PET	=	Potential evapotranspiration (mm)
Rs	=	Solar radiation (cal cm^{-2} day^{-1})
n	=	No. of days [for a 1 month period 0.013 (n = 0.4), except for February where, 0.013 (n = 0.37)]
T	=	Average air temperature (°C)
RH	=	Relative humidity (%)

Hence, the bioclimatic tolerance range of the Boz pırnal oak will be defined according to four quantitative variables; the humidity category (Q_2), the winter variant (m), the LDS and the severity of the dry season calculated according to DSWD.

Climatic data: The climatic data used in this research are meteorological records from stations located in Turkey. Twenty eight meteorological stations were selected in Turkey (Fig. 2, Table 3). The annual average rainfall of each station (P) refers to the period between 1975 and

Table 3: Characteristics and climatic data of the 28 Turkish meteorological stations nearby the stations studied

Station No.	Station name	Altitude	Latitude (N)	Longitude (E)	P (mm)	M (°C)	m (°C)	Q_2	LDS (months)	*DSWD
1	Kuyucak	100	37.55	28.28	482.2	36.7	3.2	49	4	-
2	Nazilli	60	37.55	28.19	584.7	35.8	3.2	61	4	-560
3	Germencik	45	37.52	27.36	525.1	35.6	2.1	54	4	-
4	Kuşadası	22	37.52	27.15	615.9	31.2	5.4	82	5	-645
5	Aydın	56	37.51	27.51	625.4	36.1	4.1	67	4	-568
6	Umurlu	70	37.51	27.58	480.2	36.0	2.3	49	5	-
7	Denizli	426	37.47	29.05	555.7	34.3	2.2	59	4	-447
8	Honaz	550	37.46	29.16	505.6	34.0	4.0	58	2	-
9	Koçarlı	80	37.46	27.42	443.5	35.3	3.0	47	4	-
10	Söke	75	37.45	27.25	826.0	32.2	5.2	105	4	-
11	Cine	90	37.37	28.04	533.6	36.8	3.0	54	4	-
12	Didim	330	37.21	27.15	596.3	33.6	6.8	76	5	-
13	Yatağan	365	37.21	28.08	649.6	35.0	2.3	68	4	-612
14	Milas	52	37.19	27.47	698.4	35.7	4.7	77	4	-466
15	Muğla	646	37.13	28.22	1158.8	33.3	1.5	125	3	-353
16	Bodrum	27	37.03	27.26	676.3	34.0	8.1	89	5	-666
17	Köyceğiz	24	36.58	28.41	1079.8	36.3	3.9	114	4	-480
18	Antalya	51	36.53	30.42	1132.9	34.5	5.6	134	4	-598
19	Marmaris	19	36.51	28.16	1211.7	34.4	7.0	151	4	-532
20	Ortaca	10	36.50	28.46	1088.4	35.3	6.0	126	5	-
21	Dalaman	13	36.45	28.47	969.6	33.8	5.7	118	4	-539
22	Datca	30	36.45	27.40	679.8	32.0	9.3	102	5	-
23	Fethiye	3	36.37	29.07	813.7	34.3	5.3	96	5	-681
24	Kemer	10	36.36	30.34	1046.9	35.0	6.0	123	4	-
25	Kumluca	60	36.23	30.17	788.0	33.1	6.5	101	5	-
26	Finike	3	36.18	30.09	944.2	34.1	7.2	119	4	-489
27	Kale	25	36.15	29.57	807.2	33.4	5.2	98	5	-
28	Kaş	5	36.12	29.39	784.1	32.3	9.5	117	5	-

*DSWD were calculated for the data 14 out of 28 stations due to lack of unrecorded data

2006 (31 years). The different average values of temperature, i.e., minimum of the coldest month (m), maximum of the hottest month (M) and the monthly mean temperature have been calculated for the period 1986-2006 (20 years). The basic climatic data have been provided by the Turkish Meteorological Center.

RESULTS

The categories of humidity and the winter variants can be graphically displayed on a climagram (Fig. 2).

Differences in humidity category: The Q_2 values of the regions which Boz Pırnal oak placed are as follows: Marmaris 151; Antalya 134; Ortaca 126; Muğla 125; Kemer 123; Finike 119; Dalaman 118; Kaş 117; Köyceğiz 114; Söke 105; Datça 102; Kumluca 101; Kale 98; Fethiye 96; Bodrum 89; Kuşadası 82; Milas 77; Didim 76; Yatağan 68; Aydın 67; Nazilli 61; Denizli 59; Honaz 58; Çine 54; Germencik 54; Kuyucak 49; Umurlu 49; Koçarlı 47. As it can be easily seen from these data, minimum and maximum tolerance values are between 47 (Koçarlı) and 151 (Marmaris).

Differences in winter variants: The cool category stations were: Germencik, Umurlu, Denizli, Yatağan, Muğla (0°C < m < +3°C). Moderate stations were: Kuyucak, Nazilli, Kuşadası, Aydın, Honaz, Koçarlı, Söke, Çine, Didim, Milas, Köyceğiz, Antalya, Ortaca, Dalaman, Fethiye, Kemer, Kumluca, Kale (+3°C < m < +7°C). Warm stations were: Bodrum, Marmaris, Datça, Finike, Kaş (+7°C < m < +10°C).

In fact, these results show that no winter variant can be designated as the predominant characteristic of the bioclimatic niche of Boz Pırnal oak in Turkey. When considering simultaneously the very wide range of Q_2 values and the great diversity of winter variants on the climagram, it appears that Boz Pırnal oak occurs throughout Turkey in at least 6 different types of bio climates.

Characteristics of the dry season: The LDS values of the regions which Boz pırnal oak are as follows: In Kuşadası, Bodrum, Datça, Fethiye, Kumluca, Kale, Kaş, Umurlu, Didim and Ortaca 5 months lasts; in Kuyucak, Nazilli, Germencik, Aydın, Denizli, Koçarlı, Söke, Çine, Yatağan, Milas, Köyceğiz, Antalya, Marmaris, Dalaman, Kemer, Finike 4 months lasts. In Muğla 3 months, in Honaz 2 months lasts. These data shows that dry seasons lasts between May and September months.

The DSWD values of the regions which Boz pırnal oak placed are varied as follows: In Fethiye -681; Bodrum -666; Kuşadası -645; Yatağan -612; Antalya -598; Aydın -568; Nazilli -560; Dalaman -539; Marmaris -532; Finike -489; Köyceğiz -480; Milas -466; Denizli -447; Muğla -353. These values showed that minimum and maximum DSWD values -353 in Muğla and -681 in Fethiye.

When the meteorological data obtained from nearby stations of the study areas applied to the oak communities the average annual temperature and rainfall are observed as following: 17-18°C, 443.5-1211.7 mm. These results show that habitat of the Boz pırnal oak's humid requirement could be ranged as semi-arid, sub-humid and humid. According to classification of winter variant, it ranges from cool to warm. When present findings compared with the report of Dufour-Dror and Ertas (2004), the humidity categories data of *Quercus ithaburensis* subsp. *macrolepis* were found to be similar to that of Boz Pırnal Oak. On the other hand, in the winter variant classification, *Quercus ithaburensis* subsp. *macrolepis* demands changes from very cold to warm.

DISCUSSION

The range of humidity categories: Twenty eight meteorological station's data were classified as extremely humid, sub-humid, semi-arid for identifying their moist categories. According to this classification, 13 stations were in extremely humid, 10 stations were in sub-humid, 5 stations were in semi-arid.

The diversity of winter variants: The m values of 28 stations varied between 1 and 9°C. In winter variants categories, 5 of them were in cool, 18 of them were in temperate and 5 of them were in warm region.

The bioclimatic tolerance range as an indicator of the Boz Pırnal oak climatic requirements: Because climatic constraints affect plant physiology, climate is the major abiotic factor that determines plant species geographical range when it is considered at macro-regional and global scales (Hengeveld, 1990; Cox and Moore, 1999). Consequently, the extent of occurrence Gaston (1991) of terrestrial plant species depends, at macro-scales, upon the climate characteristics and chiefly upon the temperature and the wetness or dryness of the climate considered. As a result, the edges of plant distributions often coincide with iso-lines of climatic variables (Huggett, 1998). Numerous examples of climatically limited distributions of terrestrial plants are found in the literature (MacArthur, 1972; Hengeveld, 1990; Brown *et al*., 1996; Cox and Moore, 1999).

Climate is certainly not the only factor that determines Boz pırnal oak distribution in Turkey. Other abiotic factors, such as soil properties, may influence this distribution. Boz pırnal oak are common in soil kinds having doline, polye and karstic types (Atalay, 2002). Similarly, biotic factors, i.e., interactions of organisms with one another, can place constraints on plant species distributions (Brown and Lomolino, 1998; Cox and Moore, 1999). Yet, it is important to stress that the influence of these non-climatic factors remains limited mainly to the properties of the internal structure of the geographical ranges (Brown *et al*., 1996), or, in other words, to the traits of the areas of occupancy (Gaston, 1991) found within the extent of occurrence of the species considered.

Geographically speaking it means that the influence of non-climatic factors, both abiotic and biotic, on the spatial distribution of plants species may be significant yet mostly at local and mesoscales. Therefore, when the Boz pırnal oak distribution range is considered at the spatial scale in Turkey, the most salient natural factor that may explain its extent of occurrence is likely to be the climate. Yet, studying the current geographical distribution of a widespread tree species in Turkey requires special attention to historical factors as human interferences in the natural vegetal landscapes (Talhouk *et al*., 2001).

Characteristics of the bioclimatic niches of the Boz Pırnal oak: The bioclimatic tolerance range and the niche concept: The niche concept encompasses three major attributes: the niche refers, to the functional role of the species in the bioclimatic tolerance ranges of Boz Pırnal oak ecosystem, to the characteristics of the habitat(s) where it lives and to the traits of the geographical area where the species is found (Kimmins, 1997). Obviously, the definition of the total niche of a species is very complex for it involves a very large number of variables, both biotic and abiotic. Therefore, it must be stressed that, in the present study, we propose to focus only on the third attribute of the niche concept, i.e., its distributional characteristics. If we assume, in a biogeographical perspective, that the geographical range of a species can be viewed as a spatial reflection of its niche (Brown and Lomolino, 1998) and considering present assumption that the extent of occurrence of the Boz Pırnal oak is climatically limited-as shown previously-then, the definition of the bioclimatic tolerance range of the Boz Pırnal oak can actually be regarded as a definition of their bioclimatic niche. In concrete terms this bioclimatic niche is determined according to four bioclimatic variables: a humidity category (Q_2), a winter variant, LDS and DSWD. The reference to these four quantitative bioclimatic variables can actually be seen as an application of the concept of multidimensional ecological niche (Schoener, 1988).

Two important points must be stressed when referring to the bioclimatic niche of Boz pırnal oak: first, it refers only to a specific abiotic aspect, i.e., the bioclimate, of the physical environment where the Boz Pırnal oak lives. Therefore, the definition of the bioclimatic niche shall be considered as a preliminary stage towards the complex definition of the total ecological niche that implies references to biotic variables and to additional abiotic parameters such as soil properties. Secondly, it must be kept in mind that the bioclimatic niche, as defined in the present study, is relevant only within regions experiencing a Mediterranean climate. However, the definition of the bioclimatic niche of Mediterranean species gives the possibility to characterize accurately their bioclimatic requirements. One of the main factors for extent of occurrence of Boz Pırnal oak is interpretation of the relation between climatic data and bioclimatic appropriateness. The extent of the bioclimatic tolerance range of Boz Pırnal oak is schematically displayed on Emberger's climagram in Fig. 2.

The bioclimatic tolerance range of Boz Pırnal oak is remarkably large as it includes up to 8 different types of Mediterranean bioclimate (Fig. 2). Therefore, the bioclimatic niche of the Boz Pırnal oak in Turkey is characterized by highly heterogeneous; cool-humid, cool-subhumid, cool-semiarid, temperature-humid, temperature-subhumid, temperature-semiarid, warm-humid, warm-subhumid. These findings for *Quercus ithaburensis* subsp. *macrolepis* (Palamut meşesi in Turkish): very cold-semi arid, cold semi-arid, cold sub-humid, cool semi-arid, cool sub-humid, cool humid, temperate sub-humid, temperate humid, warm sub-humid and warm humid. This is characterized by 10 different Mediterranean bioclimatic types.

In conclusion, when ecological and bioclimatic appropriateness for Boz pırnal oak assessed, its extent of occurrence is depended on lasting of the dry seasons as well as meeting its humid requirements. Present methodological results showed that optimum annual temperature averages for Boz pırnal oak is 17-18°C. Its annual rainfall demand is 600-1200 mm. Its bioclimatic classification could be established as per-humid and very cold. Overall results support that Boz pırnal oak prefers humidly ambient. Finally, its spread areas should be protected as taking them in conservation area. These kinds of taxa are the richness of the Anatolian peninsula and would be passed as whole to the next generations.

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