Determining Environmental Factors Affecting Bird Diversity

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Abstract

Aim of study: The main purpose of the study is to determine the site factors affecting bird diversity.

Area of study: This study was performed in the Çandır District, Isparta which is located inner part of the Western Mediterranean region.

Material and methods: In present study, Observations were conducted regularly in a total of 43 sample sites in Çandır District, throughout each month in 2016. Also, each sample site was observed using point-counting techniques from the direct observation techniques. In the present study, alpha diversity (Species richness, Menhinick, Margalef, Shannon-Wiener, Brillouin, Simpson, Berger-Parker, and Fisher's Alpha) values were calculated, and significant variables were determined by using correlation analysis.

Main results: A significant correlation (p=0.05) was determined between alpha diversity values and both environmental and climatic variables. Principal component analysis (PCA) was used to compare alpha diversity indexes with each other. Species richness, Shannon, and Brillouin indexes were determined as the variables having the strongest correlation with environmental variables.

Highlights: A better understanding of factors affecting bird species diversity, which are sensitive species of ecosystems, is of great importance for the detection and monitoring of future changes. Especially when it is considered in terms of parameter selection for modeling studies, the mentioned importance increases even more. Therefore, it is thought that the results of this research will be important both in terms of studies conducted in Çandır District and in terms of studies on bird diversity.

Keywords: Alpha Species Diversity, Bird Density, Correlation, Ecosystems, Principal Component Analysis

Kuş Çeşitliliğini Etkileyen Çevresel Faktörlerin Belirlenmesi

Öz

Çalışmanın amacı: Bu çalışmanın ana amacı kuş çeşitliliğini etkileyen çevresel faktörlerin belirlenmesidir.

Çalışma alanı: Çalışma Batı Akdeniz Bölgesinin iç kesimlerinde yer alan Isparta ilinin Çandır yöresinde gerçekleştirilmiştir.

Materyal ve yöntem: Çalışmada 2016 yılında aylık olarak düzenli şekilde gerçekleştirilen arazi gözlemlerinden elde edilen 43 örnek alan verisi kullanılmıştır. Her bir örnek alanda noktada sayım tekniği ile gözlemler gerçekleştirilmiştir. Çalışmada alfa çeşitlilik indeksleri hesaplanarak korelasyon analizi ile bu indisler ile ilişkili olan çevresel değişkenler belirlenmiştir.

Temel sonuçlar: Alfa çeşitlilik indeksleri ile hem çevresel değişkenler hem de iklim değişkenleri arasında önemli ilişkiler (p=0.05) tespit edilmiştir. Temel Bileşenler Analizi kullanılarak alfa çeşitlilik indislerinin birbirleri ile olan ilişkileri ortaya koyulmuştur. Tür zenginliği, Shannon indeksi, ve Brillouin indeksi değişkenler ile en yüksek korelasyon gösteren değişkenler olarak tespit edilmiştir.

Araştırma vurguları: Ekosistemlerin hassas türlerinden olan kuşlara ait çeşitliliği etkileyen faktörlerin belirlenmesi, gelecekteki değişimlerin tespiti ve izlenmesi açısından büyük önem taşımaktadır. Özellikle modelleme çalışmaları için parametre seçimi bakımından düşünüldüğünde bu önem daha da artmaktadır. Bu nedenle, bu araştırmanın sonuçlarının hem Çandır İlçesi'nde yapılan çalışmalar açısından hem de kuş çeşitliliği üzerine yapılmış çalışmalar açısından önem arz edeceği düşünülmektedir.

Anahtar Kelimeler: Alfa Tür Çeşitliliği, Kuş Yoğunluğu, Korelasyon, Temel Bileşenler Analizi

Introduction

Biological diversity values are the most important parameters that indicate the liveliness of ecosystems (Walker, 1995). Biological diversity indexes, which are indicators of biological diversity are an easy tool to monitor the continuity and permanency of ecosystems. A significant part of the global biological diversity is attributed to the diversity of birds (Tews et al., 2004; Sutherland, et al. 2010; Katayama et al., 2014). Birds play very important roles in ecosystems, for example, they control harmful insect and rodent populations, pollinate certain plants, contribute to organic substance cycles, and they promote environmental health by consuming carrion in nature (Oğurlu, 2000; Sekercioglu & Riley, 2005; Öztürk & Tabur, 2016). Birds are also rapidly affected by changes in environmental and climatic factors, and are, therefore, considered to be the most important indicator species for the sustainability of ecosystems (Burger & Gochfeld, 2004).

Turkey is characterized by different habitat types as a result of its various climatic and topographic properties and this habitat diversity has resulted in the unique occurrence and richness of species (Grumbin, 1994). Bird diversity is known to approximately represent the total diversity of the ecosystem (Reif et al., 2016). The successful protection and management of the diverse array of bird species in Turkey can only be achieved with an understanding of their relations with environmental, climatic, and topographic factors (Donald et al., 2002; Kosicki & Chylarecki, 2012). The potential impacts of these factors and the consequent temporal changes that occur can be estimated by determining which of these factors are more influential (Grumbin, 1994).

Many different indexes and mathematical formulas are used to calculate the alpha, beta, and gamma diversity values as components of biological diversity (Özkan, 2016). The alpha diversity indexes are comprised of traditional alpha diversity indexes and character-based alpha diversity indexes (Jost, 2006; Özdemir et al., 2017). Traditional alpha diversity indexes constitute the indexes that are based on the proportional or numerical values of the abundance data and species richness measurements (Özkan, 2016).

In this study, bird species diversity was calculated using various indexes based on the species richness calculation, which is among the first specified alpha diversity indexes. These indexes were then compared with each other with the aim of determining which environmental factors may account for the observed differences.

Materials and methods

Study Area

The study area covered a total of 60840 ha and was located in the city of Isparta District of Sutculer Village of Çandır (latitude: 37º 31″ 22′ and 30º 42″ 35′ N, longitude: 37º 16″ 40′ and 30º 56″ 49′ E). Nikon Monarch 12 × 42 binocular, a D-SLR camera and 400 mm telelens, a GPS, and study registration cards were used to conduct bird observations within the study area. Observations were conducted regularly in a total of 43 sample sites, throughout each month in 2016. Observations were conducted during 3 hours after dawn and for 3 hours before dusk each day, i.e., the times in which birds are most active, to obtain the required data of each observed bird species.

The slope, aspect, elevation, topographic position index(tpi), landform classification (lpi), slope position (sloppos), solar illumination (si), ruggedness, radiation index (ri), and heat index (hi) base variables of the study area were used and all of these variables were constructed using the program ArcMap 10.2 (Mert & Kıraç, 2017).

The areas of the sample sites were then overlaid with the base variables and the cellular values corresponding to these points were attained. Climatic data were downloaded as 19 bio-climate data from www.wordclim.org and these data were adjusted to the scale of the study area.

Data Analysis

In the statistical process, a factor analysis based on the Principal component analysis (PCA) was first applied to enable the selection of the representative variables among the bio-climatic variables. As a result of this process, one component was

identified to account for 48.37% of the observed variance. This component was thus selected as the representative variable [bio1 (r: 0.788)].

Species richness (S) (Peet, 1974), Menhinick (D_{MN}) (Whittaker, 1977), Margelef (D_{MG}) (Margalef, 1968), Shannon entropy (H) (Shannon, 1948), Brilluoin (HB) (Pielou, 1975), Simpson's 1-dominance ($1–\lambda$) (Simpson, 1949), Fisher's Alpha (αF) (Thomas & Shattock, 1986), and Berger-Parker ($1/d$) (Berger & Parker, 1970) indexes have been used to measure the traditional alpha diversity of bird species (Özkan, 2016). Principal components analysis (PCA) was used to determine the distances of the calculated diversity indexes on the ordination axes and Pearson correlation analysis was applied to clarify the relationship between the diversity values and environmental and climatic variables. In the present study, factor analysis, correlation analysis, and PCA were run via RStudio (RStudio Team, 2020). BİÇEB software was also used for diversity calculations (Özkan et al., 2020).

$$S= \sum_{i=1}^{s} s_i \tag{1}$$

$$H= \sum_{i=1}^{s} p_i \ln p_i \tag{2}$$

$$1–\lambda=1- \sum_{i=1}^{s} p_i^2 \tag{3}$$

$$HB= \frac{\ln N! – \sum \ln n_i!}{N} \tag{4}$$

$$1/d= \frac{N}{n_{max}} \tag{5}$$

$$D_{MN}=S/\sqrt{N} \tag{6}$$

$$D_{MG}=(S–1)/\ln N \tag{7}$$

$$\alpha_F= \frac{N(1–x)}{x} \tag{8}$$

Results

The species richness, Simpson, Brilluoin, Shannon-Wiener, Menhinick's, Margalef, Fisher's Alpha, and Berger-Parker index values of the 43 sample sites, calculated based on the diversity indexes, are shown in Table 1.

Table 1. Alpha diversity index values calculated for sample areas

Sample Area	Species Richness	Simpson	Shannon-Wiener	Brillouin	Menhinick	Margelef	Fisher's-Alpha	Berger Parker	Sample Area	Species Richness	Simpson	Shannon-Wiener	Brillouin	Menhinick	Margelef	Fisher's-Alpha	Berger Parker
s1	25	0.91	2.77	2.38	2.87	5.54	12.99	5.84	**s23**	10	0.85	2.04	1.82	1.27	2.18	3.37	4.13
s2	22	0.93	2.82	2.45	2.51	4.83	10.29	6.42	**s24**	8	0.80	1.76	1.58	1.05	1.72	2.52	3.62
s3	22	0.90	2.59	2.30	2.19	4.55	8.67	5.05	**s25**	20	0.90	2.52	2.25	2.03	4.15	7.64	6.47
s4	17	0.92	2.66	2.32	2.02	3.75	7.08	7.10	**s26**	14	0.89	2.35	2.15	1.33	2.76	4.24	6.94
s5	16	0.88	2.39	2.11	1.82	3.45	6.14	4.81	**s27**	11	0.85	2.03	1.83	1.30	2.34	3.62	4.50
s6	9	0.81	1.90	1.63	1.37	2.13	3.47	3.07	**s28**	17	0.91	2.53	2.30	1.60	3.39	5.55	7.06
s7	7	0.76	1.62	1.41	1.09	1.62	2.43	2.93	**s29**	18	0.91	2.58	2.32	1.77	3.66	6.28	6.50
s8	11	0.78	1.96	1.62	1.78	2.75	5.19	2.37	**s30**	13	0.85	2.13	1.89	1.54	2.82	4.67	4.73
s9	18	0.89	2.49	2.21	1.90	3.78	6.77	5.62	**s31**	13	0.83	2.06	1.79	1.69	2.94	5.16	4.21
s10	12	0.87	2.21	1.98	1.37	2.53	3.98	5.13	**s32**	14	0.88	2.32	2.07	1.60	2.99	5.01	5.13
s11	16	0.89	2.45	2.18	1.73	3.37	5.79	5.73	**s33**	17	0.90	2.46	2.20	1.79	3.56	6.20	6.00
s12	17	0.91	2.62	2.31	1.93	3.67	6.70	6.00	**s34**	16	0.89	2.42	2.13	1.89	3.51	6.38	5.54
s13	18	0.91	2.57	2.34	1.66	3.56	5.92	7.37	**s35**	15	0.84	2.21	1.87	2.08	3.54	7.06	3.25
s14	18	0.92	2.68	2.42	1.79	3.68	6.37	8.42	**s36**	27	0.94	3.03	2.66	2.67	5.62	11.99	6.37
s15	12	0.87	2.22	1.94	1.56	2.70	4.55	4.21	**s37**	22	0.92	2.70	2.43	2.06	4.43	8.11	7.12
s16	9	0.86	2.09	1.78	1.46	2.20	3.73	4.75	**s38**	16	0.85	2.31	1.89	2.50	4.04	9.65	3.42
s17	24	0.94	2.97	2.58	2.67	5.23	11.52	9.00	**s39**	18	0.90	2.51	2.25	1.85	3.73	6.58	5.94
s18	22	0.92	2.78	2.39	2.61	4.93	10.92	6.46	**s40**	16	0.90	2.41	2.18	1.58	3.24	5.33	7.28
s19	16	0.92	2.59	2.26	1.97	3.58	6.72	8.25	**s41**	17	0.92	2.62	2.38	1.64	3.42	5.70	7.65
s20	11	0.85	2.11	1.83	1.51	2.52	4.22	4.08	**s42**	18	0.91	2.58	2.32	1.83	3.72	6.51	7.46
s21	14	0.89	2.38	2.09	1.72	3.10	5.44	4.71	**s43**	14	0.88	2.31	2.05	1.66	3.05	5.22	6.46
s22	10	0.87	2.10	1.90	1.18	2.10	3.15	5.14									

The PCA, conducted to compare the alpha diversity indexes, produced 8 axes.

The PC1 and PC2 were found to have variances higher than 1% and ratios of

participation to the variance higher than 10% (Table 2).

Table 2. Results of the PCA

Axes	Eigenvalue	Variance (%)	Cumulative Variance (%)
Axis1	6.666	83.33	83.336
Axis2	1.131	14.19	97.475

Considering the relations among diversity values and the axes grouping them, Axis 1 was shown to be highly positively correlated with all diversity indexes and Axis 2 was shown to be partly negatively correlated with only Menhinick's index (Table 3).

Table 3.Pearson correlation analysis results applied between diversity values and axes

Diversity Values / Axes	PC 1	PC 2
Species Richness	0.977	-0.084
Simpson 1-D	0.886	0.396
Shannon	0.980	0.159
Brillouin	0.950	0.293
Menhinick	0.859	**-0.451**
Margalef	0.962	-0.229
Fisher's alpha	0.896	-0.384
Berger-Parker	0.729	**0.636**

All diversity values were then visualized on Axis 1 – Axis 2 axes to clarify the distribution of diversity indexes on the axes (Figure 1).
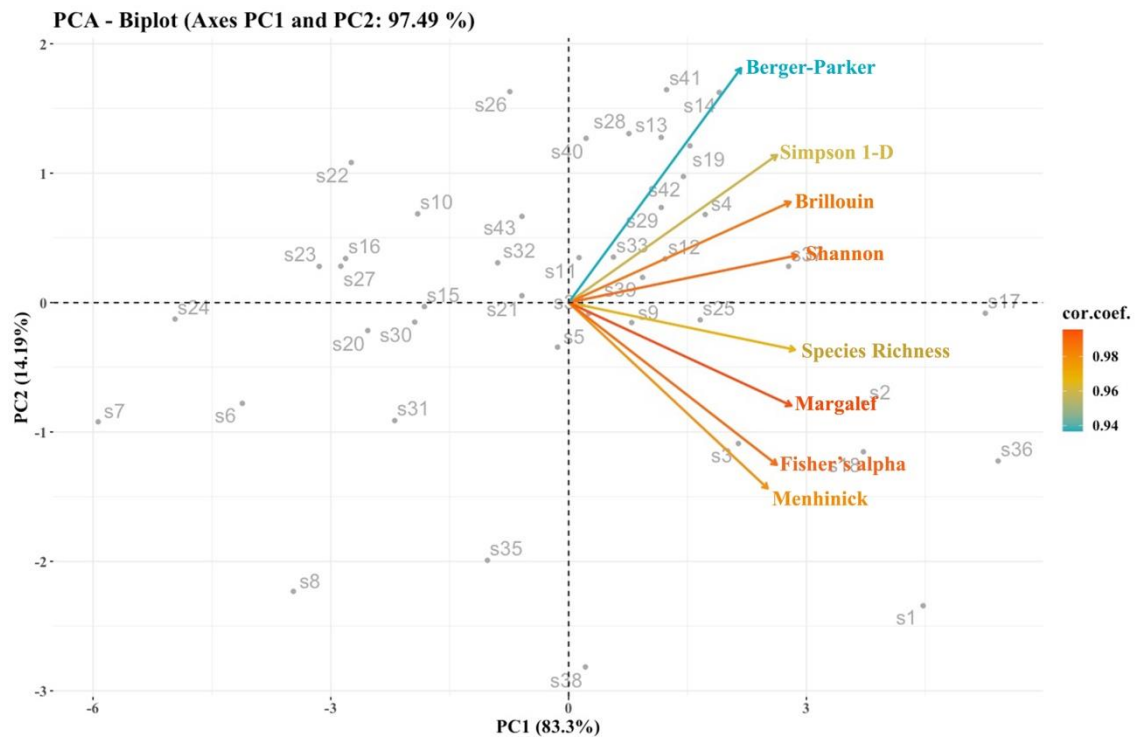

Figure 1. PCA results of the alpha diversity indexes

The PCA analysis revealed that species richness measurement and heterogenic indexes occurred in different groups depending on their axes.

The results of the Pearson's correlation analysis, which was conducted to assess the relationships between the alpha diversity indexes and variables and, thus, determine the factors that affected the diversity of the bird species, are shown in Table 4.

Table 4. Pearson Correlation results applied between alpha diversity indexes and environmental variables

Diversity Indexes / Variables	elevation	bio1	sloppos	hi	ri	lpi	4pm	2pm	8am	6am
Species Richness	r: -0.431 p: 0.004	r: -0.461 p: 0.002	r: -0.350 p: 0.021	r: -0.382 p:0.011	r: 0.371 p:0.014	r: -0.367 p:0.016	r: 0.302 p:0.049	r: -0.327 p:0.033		r: -0.317 p:0.038
Menhinick	r: -0.333 p:0.029	r: 0.411 p:0.006			r: 0.313 p:0.041					
Margalef	r: -0.407 p:0.007	r: 0.458 p:0.002	r: -0.317 p:0.038	r: -0.359 p:0.018	r: 0.359 p:0.018	r: -0.333 p:0.029				
Berger-Parker		r: 0.322 p:0.036					r: 0.354 p:0.020	r: 0.333 p:0.029	r: -0.369 p:0.015	r: -0.344 p:0.024
Fisher's alpha	r: -0.362 p:0.017	r: 0.425 p:0.005		r: -0.335 p:0.028	r: 0.347 p:0.022					
Brillouin	r: -0.384 p:0.011	r: 0.430 p:0.004	r: -0.344 p:0.024	r: -0.322 p:0.035		r: -0.352 p:0.021	r: 0.368 p:0.015	r: 0.364 p:0.016	r: -0.364 p:0.017	r: -0.356 p:0.019
Shannon	r: -0.375 p:0.013	r: 0.441 p:0.003	r: -0.331 p:0.030	r: -0.322 p:0.035		r: -0.338 p:0.027	r: 0.339 p:0.026	r: 0.342 p:0.025	r: -0.331 p:0.030	r: -0.332 p:0.030
Simpson	r: -0.304 p:0.047	r: 0.388 p:0.010	r: -0.322 p:0.035			r: -0.325 p:0.034	r: 0.357 p:0.019	r: 0.347 p:0.023	r: -0.355 p:0.019	r: -0.340 p:0.026

Species richness was found to be negatively correlated with altitude, annual average temperature, slope position, heat index, landform classification, and solar illumination (2 p.m. and 6 a.m.), and was found to be positively correlated with the radiation index and solar illumination (4 p.m.). Menhinick's index was shown to be negatively correlated with altitude and positively correlated with the annual average temperature and radiation index. Consistent with the results of the Menhinick's index, the Margelef index was also found to be negatively correlated with the heat index and slope position. Fisher's Alpha index showed similar results to these two indexes. Based on the abundance data, these indexes were generally positively correlated with annual average temperature and solar illumination (2 p.m., 4 p.m.) and negatively correlated with solar illumination (8 a.m., 6 a.m.). The Brilluoin, Shannon Wiener, and Simpson's indexes were shown to generally be negatively correlated with altitude, heat index, slope position, and landform classification. Only the Simpson's index was not shown to have any correlation with the heat index.

Discussion and Conclusion

According to PCA results of the alpha diversity indexes, the species richness measurements and heterogenic indexes formed different groups. These differences may be attributed the different base acceptances used in the different formulas. Among the heterogeneity indexes, only the Fisher's Alpha index is used to conduct species richness measurements. In previous studies, this index has been shown to give similar results to the species richness measurements (Shockat et el., 2001; Negiz & Özkan, 2019).

The results of the study indicated that the bird species diversity was lower when the landform was classified as the canyon type (32%) and when the slope position was classified as "ridge" (42%). There is a known direct relation between the landform classifications and physiographic diversity (Theobald et al., 2015), and the results of the present study also indicated these factors to be important determinants of bird diversity.

All alpha diversity values were shown to be negatively correlated with altitude. Areas with higher variations in habitats and vegetation types have been shown to occur in the lower altitudes (Özkan, 2007), and both the number of species and their frequency

have been shown to decrease with an increase in altitude. The results of the present study revealed a negative correlation between the diversity indexes and the heat index, whereby the decrease in the diversity of the bird species is dependent on the changes in climatic factors, such as temperature and air motions (Robbins, 1981; Thomas & Lennon, 1999; Hitch & Leberg, 2007). On the other hand, the annual average temperature has been shown to be a factor that determines the in-year activities and migrations of birds (Peñuelas et al., 2002). The present study revealed the factors that were negatively correlated with the species richness due to the fact that temperature especially affects the area preferences of the birds throughout different time periods. However, the indexes that considered the number of individuals, as well as the number of species, were shown to be positively correlated with the annual average temperature. Temperature was not only shown to directly and positively affect the number of individuals, but also the observance frequency of the species. Observance frequency was, therefore, used as an important parameter in the calculation of diversity in this study.

The bird diversities of the different study sites were generally shown to be negatively correlated with the slope position and heat index, as well as the landform classification. It is known that animal species do not generally prefer areas that are routinized and that have a weak distribution of habitat factors, such as food and water sources (Süel, 2014; Li et al., 2017). A possible reason for the negative correlation between the slope position and landform classification and the variability values may be attributed to the fact that the majority of the study area was routinized. Again, temperature may offer a possible explanation for these findings, due to it being an important factor that affects the mobility of animals (Van Rensburg et al., 2004).

It is important to conduct bird observations during the early hours of the morning and in the evenings (Shiu & Lee, 2003). A comparison of bird diversity and solar illumination hours revealed a positive correlation with the solar illumination at 4 p.m., which is consistent with the data in published literature. Species richness was shown to be negatively correlated with afternoon solar illumination, due to most of the species showing reduced activities at 2 p.m. A negative correlation was observed between the diversity values and morning solar illumination (6 a.m. and 8 a.m.) which are convenient in terms of observation hour. The reason for this negative correlation may be explained by the fact that the morning sun reaches the area later because the study area is generally located in a canyon, therefore, the total solar illumination at these times is low, especially when compared to the daily solar illumination ratio.

In the present study, the calculation of bird diversity using different formulas revealed that the use of more than one diversity calculation method can conveniently be used to determine the factors that influence the diversity values in an area; because every diversity index works with different mathematical formulas and unique acceptances. The attained values from such calculations can differ. These differences can greatly and significantly influence the determination and interpretation of the factors that affect diversity. Various diversity indexes should, therefore, be collectively assessed in future studies to ensure higher accuracy of interpretations of influential factors and other data.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Author Contributions
Conceptualization: H.S.; Investigation: H.S.; Material and Methodology: H.S., S.Ö.; Supervision: H.S., E.T.E.; Visualization:

S.Ö.; Writing-Original Draft: H.S., D.A.; Writing-review & Editing: D.A., S.Ö.; Other: All authors have read and agreed to the published version of manuscript.

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