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RESEARCH ARTICLE

A statistical approach on distribution and seasonal habitat use of waterfowl and shorebirds in Çıldır Lake (Ardahan, Türkiye)

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Abstract

Wetlands are crucial habitats for both migrant and resident bird assemblages. The distribution and habitat preferences of birds in aquatic ecosystems are significantly influenced by environmental and ecological factors that critically impact the relevant habitats. In order to reveal the distribution and habitat preferences of the birds, many statistical models and methodologies are employed in ecology and conservation biology. Herein, we investigated the effects of year, season, habitat, and species variables on the distribution and population dynamics of waterfowls and shorebirds associated with the wetland. In this regard, field surveys were carried out in and around Çıldır Lake (Ardahan, Türkiye) between April 2017 and September 2018 to examine the distribution of waterfowls and shorebirds and variations in population sizes. As an experimental design, a stratified random sampling design was used to assess bird fauna in the four dominant habitat types (open water surface, reeds, grasslands, and agricultural areas) in the study area. Accordingly, a total of 51 waterfowl and shorebird species were identified during the study period. Of the identified families, *Anatidae* ($n = 18$), *Scolopacidae* ($n = 8$), and *Ardeidae* ($n = 8$) were the most common families. Considering bird species, common coot *Fulica atra* and mallard *Anas platyrhynchos* were the most abundant species. The dependent variable (bird populations) was compared with the independent variables (year, season, habitat, and species). The population in 2018 decreased by 13% in comparison to the population in 2017 ($p < 0.05$). Once the reed area was considered as the reference, the population density in the water surface habitat increased by 65% ($p < 0.001$). In relation to seasonal reference, a 65% increase in population growth in spring was recorded in comparison to the growth in fall ($p < 0.001$). On the other hand, no statistical differences were noted in population growth in winter and summer (($p > 0.05$). With respect to the reference species (*Anas crecca*), critical differences in species fluctuation were observed among species ($p < 0.001$). Consequently, the findings of the present study suggest that seasonal factor might be of the substantial factors linked to the habitat composition. However, more descriptive and predictive analytical methods are needed beyond classical regression approaches in habitat use and selection studies at bird ecology.

Keywords Overdispersion · Regression · Habitat selection · Wetlands · Birds

Introduction

Biological (human activities; Milsom et al. 2000; Yuan et al. 2014; Çelik and Durmuş 2020a, intraspecific and interspecfic interactions; Müller et al. 1997; Jones et al. 2014) and ecological (temperature and humidity; Gonçalves et al. 2017; precipitation, Seoane et al. 2004; Beerens et al. 2011; vegetation structure; Milsom et al. 2000; Stanevičius 2002, seasonality; Chemineau et al. 2007; Murgui 2007; Williams and Middleton 2008) factors have significant impacts on the abundance and distribution of bird populations. In this regard, a quite number of researches indicating the link between the environmental factors and abundance and distribution of the birds are available (Canterbury et al. 2000;

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Paracuellos and Telleria 2004; Newton 2008; Mengesha et al. 2011; Cabrera-Cruz et al. 2018; Soga and Gaston 2020). Seasonality is a crucial factor that influences various aspects of bird ecology, including their distribution, species diversity, migration strategy, food sources, and environmental adaptations (Newton 2007; Caula et al. 2008; Girma et al. 2017; Gomes et al. 2017; Che et al. 2018; 2019). Seasonality has a significant impact on food availability, which can lead to changes in the migratory patterns of birds. For instance, Fristoe (2015) reported that migrant birds may alter their movements in response to seasonal changes in the food supply. Similarly, Knudsen et al. (2011) found that seasonal migrations provide birds with an opportunity to mitigate fluctuations in food availability. Subsequently, it critically ensures the continuation of the generation (Beerens et al. 2011). Fluctuations in food sources depending on the season may cause birds to migrate to other areas; on the contrary, birds remain stable throughout the year in areas where there is no seasonal irregularity and other factors do not significantly change (Karr 1976; Caula et al. 2014). In another approach explaining the effects of seasonality on bird populations, the seasons were compared phenologically with special mathematical calculations. Seasonal land uses and population dynamics of birds can be estimated with this comparison (Brotons et al. 2007).

Various factors, including habitat quality and intraspecific and interspecific interactions, can play a crucial role in shaping the habitat preferences of birds for breeding and living. These factors can impact the suitability of a given habitat for different bird species (Muller et al. 1997; Jones et al. 2014). The type of habitat and its specific characteristics can provide valuable information for estimating the diversity, distribution, density, and nutritional status of birds in a given area (Çelik 2018). In addition, changes in seasonal temperature and precipitation also affect the habitats and food resources of birds (Bibby et al. 2000; Palacio and Girini 2018; Çelik and Durmuş 2017, 2020a, b a.b; Girma et al. 2017). The spatial distribution and abundance of birds can be influenced by factors such as food availability and vegetation. Studies by Waterhouse et al (2002) and Mengesha et al (2011) have shown that there is a strong relationship between vegetation structure and habitat use, which in turn affects the population density of birds. Environmental factors such as elevation, slope, and aspect can also play a role in shaping vegetation composition and structure, which in turn may impact the abundance of bird species and their habitat preference. Girma et al (2017) found evidence to support this idea. Additionally, Lincolin et al. (1998) reported that vegetation structure is a factor that affects prey availability and seasonal migration patterns of birds.

Numerous studies have investigated the relationship between habitat and wildlife using statistical approaches. For instance, researchers have examined this topic in relation to birds (Herrera 1977; Brotons et al. 2004; Seoane et al. 2005; Guisan et al. 2007; Girma et al. 2017; Çelik and Durmuş 2020a; Azizoğlu et al. 2021), mammals (Macdonald et al. 2004), and reptiles (Segurado and Araújo 2004). While numerous explanations have been proposed for the habitat selection of birds, the environmental factors that influence the suitability of nesting sites remain poorly understood. Statistical models are therefore a valuable tool for identifying the variables that affect bird habitat preferences. In this regard, a wide variety of analytical methods that identify important explanatory variables within a model with more explanatory and predictive power than classical regression approaches have been developed. Estimating the population sizes of birds in a habitat, determining the changes in population density over time, and measuring the responses of birds to environmental variables are very important in modeling studies (see Bibby et al. 1992; Johnson et al. 1997). In the study of birds, a wide range of statistical methods and models have been employed. Among these, negative binomial regression has been one of the most commonly used models (White and Bennetts 1996; Rékási et al. 1997; O'Hara 2005; Lindén and Mäntyniemi 2011; Durmuş et al. 2018; Çelik and Durmuş 2020a,b; Azizoğlu et al. 2021). Other frequently used models include loglinear regression (McCullagh and Nelder 1989; Dobson 1991), logistic regression (Stockwell and Peterson 2002; Tattoni et al. 2012), spatial regression models (Bahn et al. 2006), multivariate adaptive regression spline (MARS) (Leitão et al. 2011), and Bayesian hierarchical models (Barnagaud et al. 2014).

The population dynamics and distribution patterns of waterfowl and shorebird species in Çıldır Lake were found to be affected by multiple factors, including year, season, habitat, and species type. In particular, seasonal variations were found to be a significant factor influencing the composition of habitat. This study examined the effects of environmental factors affecting the habitat use of birds in and around Çıldır Lake (Ardahan, Türkiye) on seasonal abundance and distribution.

Methods

Study area and field surveys

Lake Çıldır (37 S 736800, 4,335,867) is located in the Ardahan province of the Eastern Anatolia region of Turkey, near the borders with Armenia and Georgia. It is one of the largest high-altitude lakes in Turkey, with a surface area of approximately 123 km^2 and a maximum depth of 42 m. The lake is surrounded by mountain ranges, with the highest peak (Supplementary Fig. 1), Mount Çıldır, reaching an elevation of 3656 m. The lake's watershed covers an area of approximately 1900 km^2 and is mostly composed of grasslands, croplands, and pastures. The climate of the region is cold and continental, with long, harsh winters and short, cool summers. The average annual temperature is around 6 °C, with January being the coldest month and July being the warmest. The region receives most of its precipitation during the winter months, in the form of snow and rain, and experiences relatively dry summers. The topography, climate, and hydrology of Lake Çıldır and its surroundings create unique habitat conditions that support a variety of plant and animal species, including waterfowl and shorebirds (Fig. 1).

Between April 2017 and September 2018, field surveys were conducted to study the distribution and population changes of waterfowl and shorebirds in and around Lake Çıldır in Ardahan, Turkey. The surveys were conducted in all four seasons; however, the harsh winter conditions in the region led to the lake surface freezing, resulting in no bird species being recorded during that time. To analyze bird diversity and abundance in various habitats around the lake, we carried out both point counts and line transect (as suggested in the literature, see Bibby et al 2000). Observations were conducted for 10 to 15 min (Lynch 1995) from dominant points, and along a predetermined route to surround the lake in different directions. Bird species seen on the line were recorded by two researchers. During the observations, the records were taken while walking, without the use of vehicles. The study area was divided into 319 UTM squares with a 1 × 1 km^2 grid design. Data was collected from approximately 211 of these squares. To represent the habitats in each UTM square, three observation points were selected, spaced at least 300 m apart. Access to these points was achieved by car or on foot for areas reachable by road, and by zodiac boat for points that could not be accessed by road. However, a few points could not be reached by all three transportation routes. At these points, dot counts were conducted using a telescope (20–40 × 60 mm). Due to the presence of lakes, deep open water surfaces, or the absence of similar possible breeding sites, some UTM squares had only one or two observation points instead of three. At a total of 569 points, the bird species and population were recorded during the study. Three observation points were

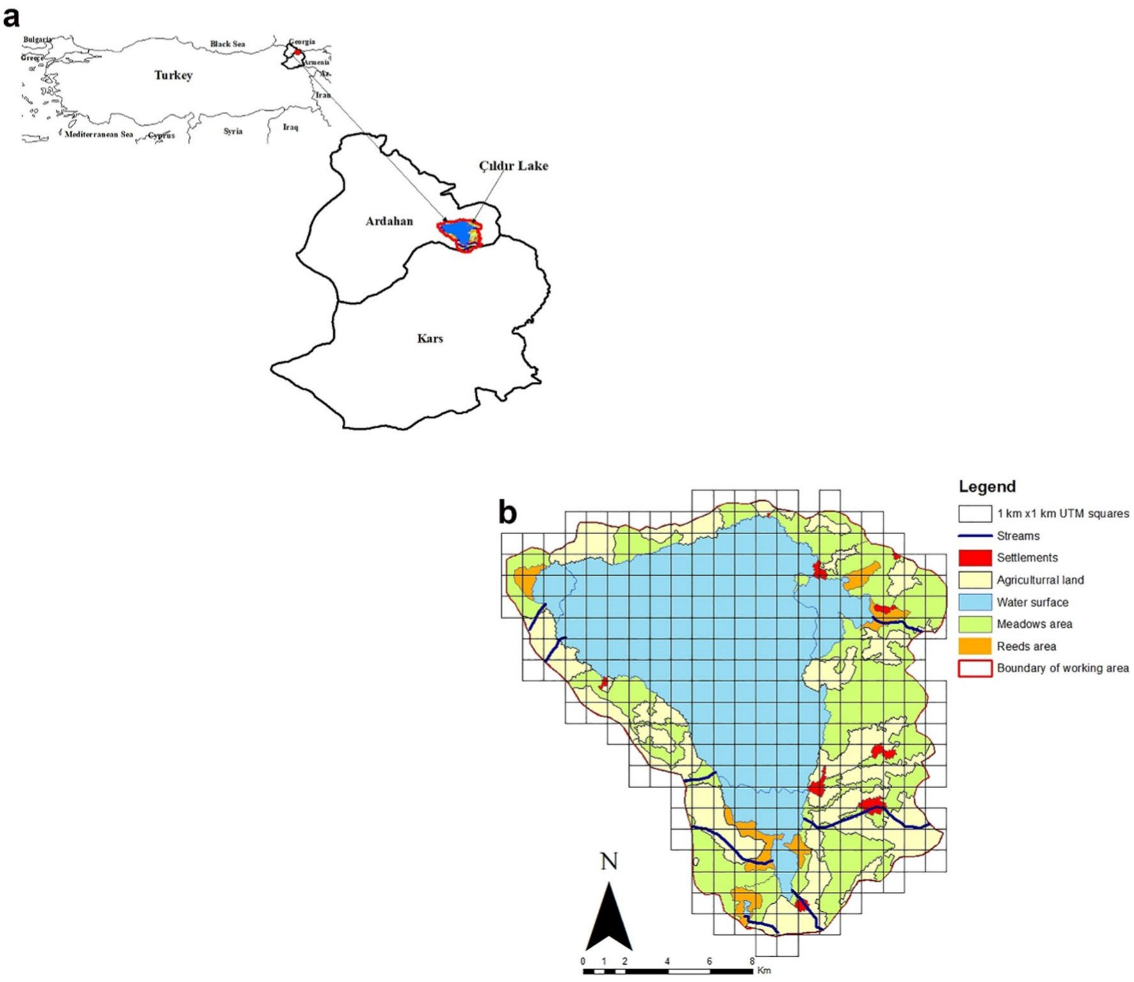

Fig. 1 **A** Study area. **b** UTM squares of 319 1 × 1 km.^{2}

Table 1 Variables used in the study

Variables	Dependent variables	Independent variables
Population	+	
Season		+
Habitat		+
Species		+
Years		+

sampled from 164 UTM squares with a 1×1 km^2, while 30 UTM squares had only two observation points and 17 UTM squares had a single observation point. Bird data were recorded on observation cards with UTM frame numbers and later transferred to a Windows Excel digital environment. Distributions were randomly generated using ESRI's ArcMap 10.2 software.

Statistical model and data analysis

The environmental and ecological factors are critical with respect to the distribution and habitat preferences of birds. Regarding revealing the relevant factors, statistical method and models are of the significant tools in ecology and conservation biology in last decades (Brambilla et al. 2009; Çelik 2018). In this context, the effects of year, season, habitat, and species on the distribution and population dynamics of each waterfowl and shorebirds were investigated (Table 1).

Overdispersion occurs when the variance exceeds the mean value of the dependent variable (Saputro et al. 2021). To calculate the level of overdispersion, the deviance statistic is divided by the degrees of freedom, as described in the literature (Yeşilova et al. 2016). According to Lindsey (1999), a value greater than one signifies overdispersion. Supplementary Table 1 presents the goodness-of-fit criteria for Poisson and negative binomial regressions used to evaluate model adequacy. The results suggest that the Poisson regression exhibited a considerably higher overdispersion value than 1.0 (15.99), indicating a significant level of overdispersion in the dependent variable. However, the negative binomial regression showed an overdispersion value closer to 1.0 (1.07), suggesting a lower degree of overdispersion in comparison.

In addition, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values of the models were also calculated and negative binomial regression with low values was considered as the most appropriate model (Sun et al. 2021) (Supplementary Table 2). The dependent variable showed a right-skewed distribution (Supplementary Fig. 2); therefore, in order to find the best model fitting data, we used both Poisson and negative binomial regressions (Cameron and Trivedi 1998). Therefore, parameter estimates were interpreted using the results of negative binomial regression.

Table 2 Parameter (year) estimates of negative binomial regression and Exp ($e\beta$) values

Parameters (year)	Estimate	Std. error	z value	Pr (>|z|)	e^{β}
(Intercept)	1.282	0.206	6.215	5.12e − 10	3.6 ***
Year 2018	− 0.139	0.064	− 2.145	0.031	0.870 *

$^{***}p < 0.001$ level, $^{**}p < 0.01$, $^{*}p < 0.05$; year reference, 2017

Table 3 Parameter (habitat) estimates of negative binomial regression and Exp ($e\beta$) values

Parameters (habitat)	Estimate	Std. error	z value	Pr (>|z|)	e^{β}
(Intercept)	1.282	0.206	6.215	5.12e-10	3.6 ***
Water surface	0.504	0.089	5.636	1.74e-08	1.65 ***
Meadow	0.108	0.104	1.037	0.299	1.11
Agricultural land	− 0.054	0.141	− 0.384	0.700	0.947

$^{***}p < 0.001$ level, ** $p < 0.01$, $^{*}p < 0.05$; habitat reference, reeds area

Table 4 Parameter (seasons) estimations of negative binomial regression and Exp ($e\beta$) values

Parameters (seasons)	Estimate	Std. error	z value	Pr (>|z|)	e^{β}
(Intercept)	1.282	0.206	6.215	5.12e-10	3.6 ***
Winter	− 0.308	0.331	− 0.930	0.352	0.734
Spring	0.501	0.074	6.726	1.74e-11	1.650***
Summer	0.002	0.102	0.029	0.976	1

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; season reference, fall

Accordingly, a 13% decrease was noted in shorebird and waterfowl population in 2018 compared to 2017 ($p < 0.05$) (Table 2).

The population density in the water surface habitat increased by 65% ($p < 0.001$) when the reed area was used as the reference. In relation to reference habitat, significant differences concerned with population changes were recorded (Table 3).

Bird populations in fall, as the reference season, decreased by 65% in comparison to the spring season ($p < 0.001$). The changes in bird populations in winter and summer seasons were statistically significant in comparison to the reference season (Table 4).

Eurasian teal *Anas crecca* was considered as the reference species. Population density compared to *A. crecca* species is higher approximately threefold in mallard *Anas* *platyrhynchos*, threefold in Armenian gull *Larus armenicus*, threefold in Northern lapwing *Vanellus vanellus*, sixfold in Ruddy shelduck Tadorna ferruginea, fivefold in Graylag goose *Anser anser*, and eightfold in little grebe *Tachybaptus ruficollis*. The highest increase (approximately 12-fold) was recorded in common coot *Fulica atra* species ($p < 0.001$). The lower in population density of Ferruginous duck *Aythya nyroca* and black stork *Ciconia nigra* species compared to Eurasian teal *Anas crecca* species was 68 and 65% ($p < 0.01$). The highest decrease in the population density compared to Eurasian teal *Anas crecca* species was recorded in Dunlin *Calidris alpina* with 76% ($p < 0.05$) (Table 5).

Poisson regression is used when a dependent variable has a Poisson distribution (Moksony 2001). Log-likelihood function for Poisson's regression model (Eq. 1) is given as follows: (Khoshgoftaar et al. 2005).

$$L(\beta/y_i, x_i) = \sum_{i=1}^{n} y_i x_i{}' \beta - \exp(x_i{}' \beta) - \ln y_i!) \qquad (1)$$

Multiple regression allows to model the relationship between a dependent variable and multiple independent variables. In the case of negative binomial regression with multiple independent variables, the formula is as below (Blackburn 2015).

$$ln(\mu) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \qquad (2)$$

μ is the mean of the dependent variable, $\ln(\mu)$ is the natural logarithm of μ, β_0 is the intercept (the value of $\ln(\mu)$ when all independent variables are equal to zero), $\beta_1, \beta_2, \ldots, \beta_{\mathrm{k}}$ are the coefficients for each independent variable (the change in $\ln(\mu)$ for a one-unit increase in each independent variable), and $x_1, x_2, \ldots, x_{\mathrm{k}}$ are the values of the independent variables (Yeşilova et al 2016).

The relevant statistical analyses were performed using R 4.0 software. MASS, foreign, AER, ggplot2, viridis, and hrbrthemes libraries were used in the software.

The reference parameter is widely used in categorized data sets. The year 2017, the reeds from the habitats, the fall from the seasons, and the Eurasian teal *Anas crecca* from the species were defined as reference in the model and the variables were analyzed according to the reference parameters. Some priorities were taken into account in determining the reference parameters in the independent variables. The migratory birds form colonies before migration in the fall season; therefore, the fall season was chosen as the reference season. The reed area is frequently preferred by shorebirds and waterfowl as the habitat; thus, the reed area was considered as the reference habitat. The waterfowl were the dominant species in the open water surface and associated habitats; thus, they were chosen as the reference bird species (Weller 1999).

Results

Fifty-one shorebird and waterfowl species belonging to 9 orders and 33 families were identified during the 2-year field studies. Of the species identified, 29.4% (*n*: 15) were resident throughout the year, 31.4% (*n*: 16) were transit migrant species which use the area for short-term accommodation and feeding, and 39.2% (*n*: 20) were summer migrant species which frequently used the area for breeding, feeding, and stopover during the summer months. Resident species during the winter months have been identified in the non-freezing streams of the region outside the study area. The observations revealed that 16 species of 51 shorebirds and waterfowls "definitely breed" in the area, 14 species "probably breed," and 21 species do not breed or display breeding behavior in the area. According to the IUCN conservation status, 86.2% (*n*: 44) of the species in the study area composed of the least threatened common species LC (least concern), 7.8% (*n*: 4) were listed as not currently endangered but may be endangered in the near future NT (near threatened), and 5.9% (*n*: 3) were at high risk of extinction VU (vulnerable) species (Table 6).

General abundance and distribution patterns

Four main habitats in Lake Çıldır were identified (reeds (1), open water surface (2), meadows (3), and agricultural areas (4)). The highest population density of the bird species (waterfowl and shorebirds) was recorded at open water surface during spring, while the lowest was observed at reed during winter. In addition, the most used habitat was open water surface where the highest population density was recorded, and the least common habitat for the species was agricultural land (Figs. 2 and 3). Bird populations were recorded in various seasons and habitats during the period of 2017–2018. The highest population of birds was observed during the spring season, with a total of 6689 individuals counted across 211 UTM squares, resulting in an average of 32 individuals per km^2 in each UTM square. On the other hand, the lowest population was observed during the winter season, with only 52 individuals counted across 8 UTM squares, resulting in an average of 6.5 individuals per km^2 in each UTM square. Regarding habitats, the open water surface habitat had the highest bird population, with 3896 individuals observed from 64 UTM squares, averaging out to 60.8 individuals per km^2 in each UTM square. On the other hand, the farmland habitat had the lowest bird population, with only 268 individuals observed from 16 UTM squares, averaging out to 16.7 individuals per km^2 in each UTM square.

Table 5 Parameter (species) estimates of negative binomial regression and Exp ($e\beta$) values

Parameters (species)	Estimate	Std. error	z value	Pr (>|z|)	e^{β}
(Intercept)	1.282	0.206	6.215	5.12e-10	3.6 ***
Anas platyrhynchos	1.225	0.221	5.530	3.20e-08	**3.387** ***
Larus armenicus	1.204	0.229	5.238	1.62e-07	**3.32** ***
Larus ridibundus	0.631	0.347	1.816	0.069	1.87
Vanellus vanellus	1.291	0.248	5.188	2.13e-07	**3.63*** **
Aythya marila	−0.726	0.402	−1.805	0.071	0.48
Aythya nyroca	−1.122	0.416	−2.697	0.006	**0.32** **
Aythya ferina	−1.108	0.255	−0.427	0.669	0.40
Tachybaptus ruficollis	2.085	0.229	9.100	<2e-16	**8** ***
Podiceps cristatus	0.041	0.242	0.170	9.100	1.04
Ciconia nigra	−1.056	0.342	−3.085	0.0204	**0.35** **
Phalacrocorax carbo	0.461	0.258	1.789	0.073	1.58
Tadorna ferruginea	1.851	0.221	8.342	<2e-16	**6.366** ***
Tringa ochropus	−0.335	0.311	−1.075	0.282	0.715
Anas acuta	−0.686	0.711	−0.964	0.334	1.985
Podiceps grisegena	0.144	0.275	0.524	0.600	1.154
Egretta garzetta	−0.427	0.277	−1.541	0.123	0.652
Ardea purpurea	−1.091	0.592	−1.841	0.065	0.335
Ardea cinerea	−0.672	0.271	−2.480	0.013	0.510 *
Spatula clypeata	0.011	0.479	0.024	0.980	1.01
Spatula querquedula	−0.682	0.357	−1.906	0.056	0.505
Aythya fuligula	−0.150	0.373	−0.404	0.686	0.860
Grus grus	−0.288	0.398	−0.723	0.469	0.749
Sterna hirundo	−0.462	0.408	−1.132	0.257	0.630
Ciconia ciconia	−0.110	0.262	−0.421	0.673	0.895
Fulica atra	2.453	0.235	10.440	<2e-16	**11.62** ***
Calidris pugnax	0.600	0.303	1.977	0.048	1.82 *
Plegadis falcinellus	0.381	0.464	0.820	0.412	1.463
Pelecanus crispus	0.249	0.276	0.905	0.365	1.282
Gallinula chloropus	−0.563	0.398	−1.411	0.158	0.569
Podiceps nigricollis	−0.868	0.734	−1.182	0.237	0.419
Pelecanus onocrotalus	0.396	0.306	1.292	0.196	1.485
Limosa limosa	−1.487	0.822	−1.808	0.070	0.226
Charadrius dubius	−0.279	0.323	−0.865	0.387	0.756
Himantopus himantopus	0.236	0.406	0.581	0.561	1.266
Bubulcus ibis	−0.408	0.339	−1.204	0.228	0.664
Ardea alba	−0.358	0.520	−0.689	0.491	0.699
Ardeola ralloides	−0.444	0.422	−1.053	0.292	0.641
Ixobrychus minutus	−1.808	0.718	−2.518	0.011	0.163 *
Tringa totanus	0.638	0.259	2.459	0.01395	1.734 *
Anser anser	1.548	0.356	4.350	1.36e-05	**4.702** ***
Calidris minuta	0.429	0.461	0.932	0.351	1.535
Calidris alpina	−1.426	0.593	−2.404	0.016	**0.240** *
Charadrius alexandrinus	−1.391	0.920	−1.512	0.130	0.248
Tringa glareola	−0.987	0.603	−1.638	0.101	0.372
Branta ruficollis	−1.787	0.915	−1.953	0.050	0.168
Tringa stagnatilis	−0.645	0.563	−1.145	0.252	0.524
Cinclus cinclus	0.289	0.637	0.453	0.650	1.335
Nycticorax nycticorax	0.127	0.492	0.259	0.795	1.135
Mareca strepera	−0.880	0.826	−1.066	0.286	0.414
Tringa nebularia	−0.988	0.828	−1.194	0.232	0.372

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$; species reference, *Anas crecca*

Table 6 Shorebirds and waterfowl species of Lake Çıldır, IUCN criteria, habitats, regional and reproductive status

Family/scientific name	English name	IUCN	Region status	Habitat type	EBCC
Podicipediformes					
Podicipedidae					
Tachybaptus ruficollis	Little grebe	LC	L	RA, WS	A
Podiceps cristatus	Great-crested grebe	LC	L	RA, WS	A
Podiceps grisegena	Red-necked grebe	LC	L	RA, WS, MA	A
Podiceps nigricollis	Black-necked grebe	LC	TI	RA	B
Pelecaniformes					
Ardeidae					
Ixobrychus minutus	Little bittern	LC	TI	RA	C
Nycticorax nycticorax	Black-crowned night heron	LC	SI	RA, WS	C
Ardeola ralloides	Squacco heron	LC	SI	RA, MA, WS	C
Bubulcus ibis	Cattle egret	LC	SI	RA, MA, AL, WS	B
Egretta garzetta	Little egret	LC	SI	RA, WS, MA, AL	C
Ardea alba	Great egret	LC	L	RA, AL	C
Ardea cinerea	Grey heron	LC	L	RA, MA, WS, AL	C
Ardea purpurea	Purple heron	LC	TI	RA	C
Pelecanidae					
Pelecanus onocrotalus	Great white pelican	LC	SI	RA, WS	A
Pelecanus crispus	Dalmatian pelican	VU	SI	RA, WS, MA	B
Suliformes					
Phalacrocoracidae					
Phalacrocorax carbo	Great cormorant	LC	L	RA, WS, MA	C
Threskiornithidae					
Plegadis falcinellus	Glossy ibis	LC	SI	RA, WS	B
Ciconiiformes					
Ciconiidae					
Ciconia nigra	Black stork	LC	SI	MA, AL, WS	A
Ciconia ciconia	White stork	LC	SI	MA, AL	A
Anseriformes					
Anatidae					
Anser anser	Greylag goose	LC	SI	MA, AL	A
Branta ruficollis	Red-breasted goose	VU	TI	WS	C
Tadorna ferruginea	Ruddy shelduck	LC	L	RA, WS, MA, AL	A
Mareca strepera	Gadwall	LC	TI	R	C
Anas crecca	Common teal	LC	L	RA, WS	B
Anas platyrhynchos	Mallard	LC	L	RA, WS, MA, AL	A
Anas acuta	Northern pintail	LC	L	RA	A
Spatula querquedula	Garganey	LC	SI	RA, WS, MA	A
Spatula clypeata	Northern shoveler	LC	SI	RA, WS	B
Aythya ferina	Common pochard	VU	SI	RA, WS, MA	B
Aythya nyroca	Ferruginous duck	NT	L	RA, WS, MA	A
Aythya fuligula	Tufted duck	LC	TI	RA, WS	C
Aythya marila	Greater scaup	LC	TI	RA, WS	C
Gruiformes					
Rallidae					
Gallinula chloropus	Common moorhen	LC	L	RA, WS, MA	B
Fulica atra	Common coot	LC	L	RA, WS, MA	B
Gruidae					
Grus grus	Common crane	LC	SI	RA, MA, AL	A

Table 6 (continued)

Family/scientific name	English name	IUCN	Region status	Habitat type	EBCC
Charadriiformes					
Recurvirostridae					
Himantopus himantopus	Black-winged Stilt	LC	SI	RA, WS, MA	A
Charadriidae					
Charadrius dubius	Little-ringed plover	LC	SI	MA, AL, WS	A
Charadrius alexandrinus	Kentish plover	LC	TI	MA	C
Vanellus vanellus	Northern lapwing	NT	SI	RA, MA, AL	A
Scolopacidae					
Calidris minuta	Little stint	LC	TI	MA, WS	C
Calidris alpina	Dunlin	LC	TI	MA, WS	C
Calidris pugnax	Ruff	LC	SI	RA, AL, MA	B
Limosa limosa	Black-tailed godwit	NT	TI	MA	C
Tringa totanus	Common redshank	LC	SI	RA, WS, MA, AL	B
Tringa stagnatilis	Marsh sandpiper	LC	TI	RA, MA	C
Tringa nebularia	Common greenshank	LC	TI	MA	C
Tringa ochropus	Green sandpiper	LC	SI	RA, WS, MA	B
Tringa glareola	Wood sandpiper	LC	TI	MA	C
Laridae					
Larus ridibundus	Black-headed gull	LC	TI	WS	C
Larus armenicus	Armenian gull	NT	L	MA, WS, AL	B
Sterna hirundo	Common tern	LC	TI	WS	C
Passeriformes					
Cinclidae					
Cinclus cinclus	White-throated dipper	LC	L	WS	B

LC least concern, *NT* near threatened, *VU* vulnerable, *L* local, *TI* transit immigrant, *SI* summer immigrant, *RA* reeds area, *WS* water surface, *MA* meadows area, *AL* agricultural area, *A* definitive breeding, *B* possible breeding, *C* not breeding, *EBBC* European Bird Census Council

Discussion and conclusion

Comprehensive research on bird diversity and population dynamics is crucial for understanding material and nutrient cycles in an ecosystem. Monitoring bird diversity in a particular habitat can provide valuable information for sustainability and wildlife preservation efforts. However, regarding the abundance and distribution; we should utter that the response of the birds to their environment is quite complex and intertwined with a plethora of biotic and abiotic factors (Rahayuninagsih et al. 2007). In particular, seasons modify the climatic structure of the region, natural resources and habitat, which in turn alter bird diversity (Caula et al. 2008; Girma et al. 2017; Che et al. 2018; 2019; Durmuş et al. 2018; Çelik and Durmuş 2020a, b; Azizoğlu et al. 2021), as the case reported for waterfowl and shorebird species in wetlands (Seoane et al. 2004). In addition, the distribution of birds in habitats can be affected by access to food sources and feeding types (Beerens et al. 2011). For instance, diving ducks and geese prefer inner open waters (Green 1998; Kristiansen 1998; Carboneras and Kirwan 2014), while shorebirds and heron birds may prefer shallow marsh and wet meadow areas (del Hoyo et al. 1996; Snow and Perrins 1998; Zöckler 2002).

Herein, the findings of the present study revealed that species, season, and habitat variables critically affected the distribution and population density of birds. As expected, the current findings are consistent with former reports indicating that species, habitat, and seasonal variables exert significant acts on bird population densities and habitat use (Murkin et al. 1997; Clark and Shutler 1999; Murgui 2007; Johnston et al. 2015; Durmuş et al. 2018; Çelik and Durmuş 2020a, b). Not only being confined to the seasons, bird species diversity and population density might be the consequences of species-specific habitat use (Hansen and Urban 1992).

Along with the findings, the distribution of waterfowl and shorebirds was found to be different corresponding to the habitats. Population density of 8 species (*Anas platyrhynchos*, *Larus armenicus*, *Vanellus vanellus*, *Tadorna ferruginea*, *Anser anser*, *Tachybaptus ruficollis*, *Fulica atra*) higher and 3 species (*Ciconia nigra*, *Aythya nyroca*, *Calidris alpina*) lower compared to *Anas crecca*, which was the reference species, while the population differences between

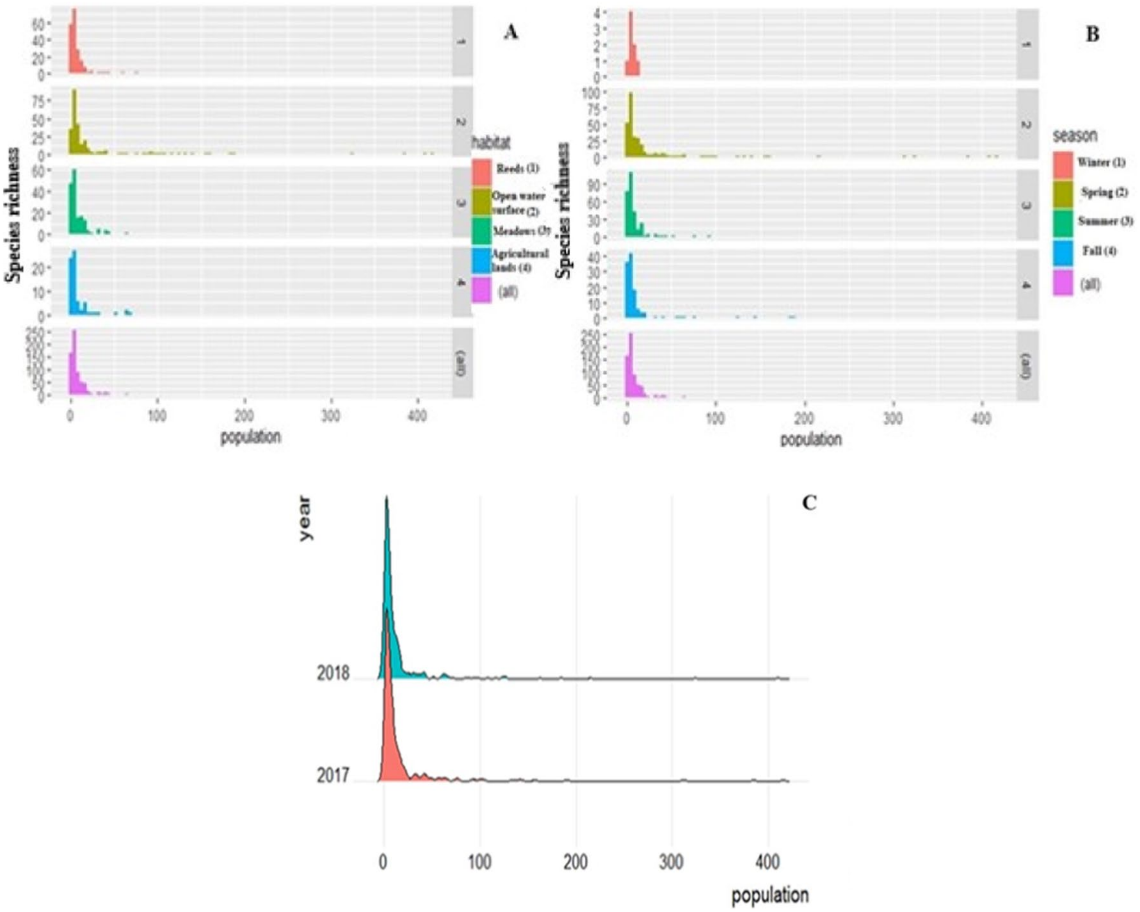

Fig. 2 Variation in abundance and richness of waterbirds and shorebirds. **A** habitat, **B** season, **C** years (the *y*-axis label "count" represents the number of species, while the *x*-axis label "population" represents density (**A**, **B**))

other coastal birds and waterfowls were not statistically significant. The population differences between species can be explained with seasonal land uses of species (Johnston et al. 2015; Çelik and Durmuş 2020a, b).

Based on field observations, it has been found that *A. platyrhynchos*, *L. armenicus*, *T. ferruginea*, *V. vanellus*, and *F. atra* species exhibit a wider tolerance for diverse habitats than *A. crecca*. *A. crecca* tends to prefer inner open waters (Elmberg et al. 2005), while other species such as *A. platyrhynchos*, *L. armenicus*, *T. ferruginea*, *V. vanellus*, and *F. atra* are known to use meadows, agricultural lands, and open water surfaces as well. The water level is a crucial factor in determining the habitat preferences of species (Colwell and Taft 2000; Elphick and Oring 2003; Hamza et al. 2015). It plays a significant role in shaping the suitability of a habitat for a particular species. The studies conducted by Colwell and Taft (2000), Elphick and Oring (2003), and Hamza et al. (2015) all indicate that water level is a critical determinant of the habitat preferences of various species. The water level of the wetland in the spring season increases with the increasing precipitation and snow melting. The increased level of water in wetland has led to an increase in the number of some swim-feeding species in the region (such as *A. crecca*, *A. platyrhynchos*, *F. atra*). The populations of bird species (*L. armenicus*, *T. ferruginea*, *V. vanellus*) feeding in both coastal and wetlands increased depending on the water level (Güitrón-López et al. 2018). However, the decrease in the water level towards the fall season caused some changes in the species composition. *A. crecca* species mostly occurs in shallow waters and flooded meadows (Rizzo and Battisti 2009), gradually left the region and population density decreased. Shorebirds (*L. armenicus*, *V. vanellus*) were abundant in the shallow habitats formed by the withdrawal of water. On the other hand, population densities of species (*A. platyrhynchos*, *F. atra*, *T. ferruginea*) that can feed in deep and shallow waters seriously decreased because these species can use both the open water surface and other habitats (reeds, meadows, swamps, etc.) associated with the wetland as a feeding area (Güitrón-López et al. 2018).

In particular, species may have different or similar habitat preferences, which in turn affect the contributions to the population densities (Johnston et al. 2015). For instance,

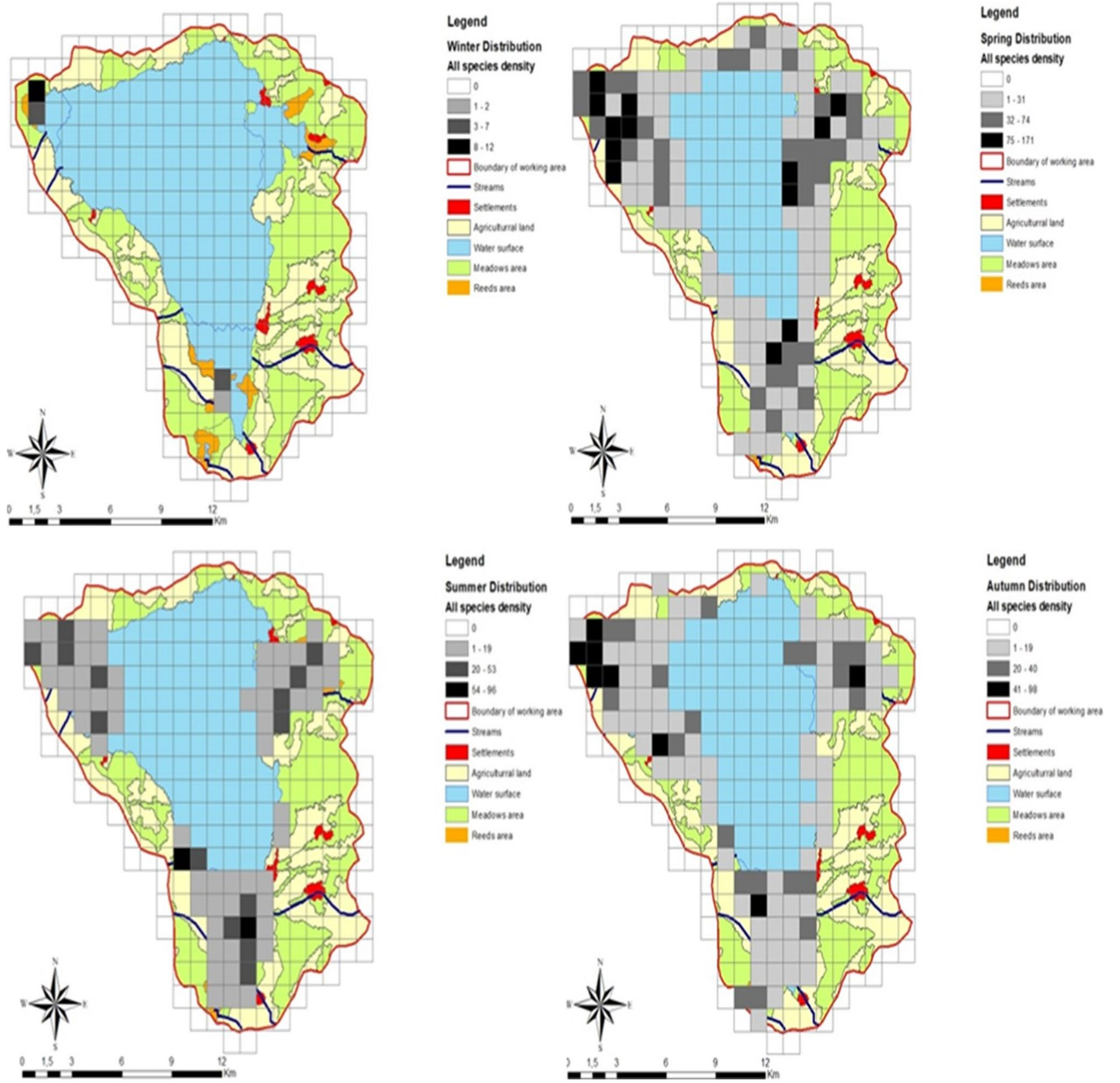

Fig. 3 Distribution maps of shorebirds and waterfowl species by seasonal habitats

species, viz. *F. atra*, *V. vanellus*, *L. armenicus*, and *T. ferruginea* form large breeding colonies in their region. On the other hand, *A. crecca* is a rare migratory bird species encountered in the area and leaves the area with the arrival of fall season. Thence, the differences in the number of species and densities of populations between the habitats might be explained with forming breeding colonies. Guisan et al. (2007) and Beerens et al. (2011) reported that habitat types and species have a significant impact on the habitat preferences and distribution of birds. Similarly, attributed the differences in the habitat preferences of the bird species are correlated to the ecological requirements of the species (Moreno et al. 2011). As expected, the current findings also suggested that the changes in habitat and vegetation densities with seasons significantly affected the number of species and populations. A statistically significant increase in population was observed in the open water surface area compared to the reed area. However, there was no significant difference in population changes or species diversity between the meadow and agricultural land areas. Among the observed families, the *Anatidae* family was found to be dominant within the study region. The *A. platyrhynchos* and *T. ferruginea* species were found to be the most dominant species in the area, primarily utilizing the open water surface for their activities. Owing to their wide tolerance concerned with habitat use, *A. platyrhynchos* and *T. ferruginea* might use other habitats such as meadow, reeds, and agricultural land, in case of critical modifications in their common habitat use. The relevant differences among species might be strongly attributed to land use differences of the birds (Quan et al. 2001; Evans and Day 2002).

The land uses of species in fall season (the reference season) were compared with the other seasons. Because of the fact that birds were not observed in harsh winter conditions and transportation difficulties of the region, winter season was not included in the comparison of population changes between seasons. Populations in the fall season significantly decreased compared to the spring season. The study area exhibited higher species richness and diversity in the spring season compared to the fall season, which can be attributed to temperature differences between the seasons, as noted by Gonçalves et al. (2017) and Kawamura et al. (2019). The rising temperatures in spring increased ornithological activity in the study area, as reported by Elsen et al. (2017). Furthermore, the population differences between seasons may be attributed to migratory species that appear in one season and disappear in the other, as noted by Newton (2008). Precipitation, an important climatic factor, significantly contributes to the enrichment of vegetation cover and water level increase, which explains population differences between seasons. Subsequently, changes in the lake mirror have created suitable feeding environments for duck and goose species that feed by diving or from the surface. Alongside this, changes in precipitation levels have led to fluctuations in vegetation patterns, including flowering and fruiting, which have subsequently boosted ornithological activity within the area (Rahayuningsih et al. 2007; Mengesha and Bekele 2008). During the fall season, there was a noticeable reduction in the size of habitats surrounding the wetland, including the reeds and meadows, which resulted in partial drying up of these areas. Consequently, birds that were commonly found in these habitats relocated away from the study region. It is worth mentioning that various factors such as seasonal changes, habitat availability, and species-specific behavior can all contribute to shaping the distribution and population dynamics of birds.

In conclusion, our study reveals the intricate and ever-changing interplay between birds, habitat, and season, which is influenced by multiple factors, such as species-specific needs, habitat type, and seasonal variations. Our findings clearly demonstrate that birds exhibit a strong affinity towards habitats that offer critical resources for their survival, including food, water, shelter, and nesting sites, and that these preferences can vary across different bird species and over the course of the year. Therefore, our results emphasize the importance of taking into account the specific habitat requirements of different bird species when developing conservation and management strategies aimed at promoting healthy and thriving bird populations. Such efforts can help ensure the long-term sustainability of these vital components of our natural ecosystems.

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Author contribution Emrah Celik (EC), Erkan Azizoglu (EA), and Rıdvan Kara (RK) designed the study and conceived the original idea for the manuscript. EA and EC carried out the fieldwork and collected the bird data. RK analyzed the data. EC wrote the manuscript. All authors read and approved the final manuscript.

Data availability Not applicable.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

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Conflict of interest The authors declare no competing interests.

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