Commagene Journal of Biology

Uysal et al., (2025) *Comm. J. Biol.* 9(1), 17-27.
DOI: 10.31594/commagene.1553393

e-ISSN 2602-456X

Research Article/Araştırma Makalesi

Analysis of Bird Populations in the Wetland Areas Surrounding the Çanakkale/Dardanelles Strait

İbrahim UYSAL[1,*], Didem KURTUL[2], Ceren Nur ÖZGÜL[2], Murat TOSUNOĞLU[3]

[1]*Çanakkale Onsekiz Mart University, Vocational School of Health Services Çanakkale, TÜRKIYE*
[2]*Çanakkale Onsekiz Mart University, School of Graduate Studies, Department of Biology, Çanakkale, TÜRKIYE*
[3]*Çanakkale Onsekiz Mart University, Faculty of Science, Department of Biology, Çanakkale, TÜRKIYE*
ORCID ID: İbrahim UYSAL: https://orcid.org/0000-0002-7507-3322; Didem KURTUL: https://orcid.org/0000-0003-0778-5966; Ceren Nur ÖZGÜL: https://orcid.org/0000-0002-1597-4321; Murat TOSUNOĞLU: https://orcid.org/0000-0002-9764-2477

Received: 20.09.2024 **Accepted:** 03.01.2025 **Published online:** 03.02.2025 **Issue published:** 30.06.2025

Abstract: Given the rapid loss of wetland ecosystems today, monitoring bird species and populations that can respond quickly to environmental changes is crucial for the effective tracking of wetland ecosystems. Additionally, wetland ecosystems are of critical importance for the life cycles and migratory movements of bird species. The aim of the study is to examine the monthly variations in bird species diversity in the wetland areas (Kavak Delta, Çardak Lagoon, Kumkale Delta, Suvla Salt Lake, and Umurbey Delta) surrounding the Çanakkale/Dardanelles Strait, located in the northeastern part of the Mediterranean basin, which plays a significant role in migration strategies for numerous bird species. Additionally, correlations between the habitat types and areas of these wetlands and their diversity indices were analyzed and updated species lists for the studied wetlands were compiled. The field studies were conducted monthly in 2023 using point and transect observation methods to assess species and population counts. Diversity indices were calculated using the number of species and individuals recorded monthly for each area. The relationship between the habitat types and the areas they cover in wetlands and the diversity indices was tested using Spearman's rho correlation analysis. A total of 184.068 birds belonging to 279 species, encompassing 22 orders and 61 families, were counted across all areas. In the wetland areas, species richness (Margalef index - M) ranged from 15.417 to 22.718 and species diversity (Shannon-Wiener Index - H') ranged from 1.819 to 2.416. The fact that the research areas lie along a significant migration route enhances species diversity and richness during migration periods. In Deltas where shallow surface waters predominate, more pronounced differences in diversity indices have been observed due to variations in seasonal water levels. A strong positive correlation was found between species richness and the size of wetlands, particularly Salt Marshes and Permanently Irrigated Lands, indicating the critical role of habitat size in supporting biodiversity. Seasonal water level fluctuations also significantly impacted diversity in delta regions. Given the global loss of wetlands, long-term research with standardized methods is crucial for understanding and protecting these vital ecosystems.

Keywords: Diversity index, ornitofauna, wetland ecosystems, correlation.

Çanakkale Boğazı Çevresindeki Sulak Alanlardaki Kuş Popülasyonlarının Analizi

Öz: Günümüzde sulak alan ekosistemlerinde yaşanan hızlı yok oluş göz önüne alındığında, yaşanan değişimlere hızlı tepki verebilen kuş türlerinin ve popülasyonlarının izlenmesi sulak alan ekosistemlerinin takibi açısından önem arz etmektedir. Aynı zamanda, sulak alan ekosistemleri de kuş türlerinin yaşam döngüsü ve göç hareketlilikleri açısından kritik öneme sahiptir. Çalışmanın amacı, çok sayıda kuş türünün göç stratejilerinde önemli rol oynayan Akdeniz havzasının kuzeydoğu kesiminde yer alan Çanakkale Boğazı çevresindeki sulak alanlardaki (Kavak Deltası, Çardak Lagünü, Kumkale Deltası, Suvla Tuz Gölü, Umurbey Deltası) kuş türü çeşitliliğindeki aylık değişimleri incelemektir. Ayrıca, bu sulak alanların habitat tipleri ve alanları ile çeşitlilik endeksleri arasındaki korelasyonlar analiz edilmiş ve incelenen sulak alanlar için güncellenmiş tür listeleri derlenmiştir. Saha çalışmaları, nokta ve transekt gözlem metodları kullanılarak 2023 yılında aylık olarak yürütülmüştür. Çeşitlilik endeksleri, her alan için aylık olarak kaydedilen tür ve birey sayıları kullanılarak hesaplanmıştır. Sulak alan alanlarındaki habitat tipleri ve kapsadıkları alanlar ile çeşitlilik indeksleri arasındaki ilişki, Spearman korelasyon analizi ile sınanmıştır. Tüm alanlarda 22 takım ve 61 familyayı kapsayan 279 kuş türüne ait toplam 184.068 birey sayılmıştır. Sulak alanlarda tür zenginliği (Margalef indeksi- M) 15.417 ile 22.718 arasında, tür çeşitliliği (Shannon-Wiener İndeksi- H') ise 1.819 ile 2.416 arasında değişmiştir. Araştırma alanlarının önemli bir göç yolu üzerinde yer alması, göç dönemlerinde tür çeşitliliğini ve zenginliğini artırmaktadır. Sığ yüzey sularının baskın olduğu deltalarda, mevsimsel su seviyelerindeki değişiklikler nedeniyle çeşitlilik indekslerinde daha belirgin farklılıklar gözlenmiştir. Tür zenginliği ile sulak alanların, özellikle tuzcul bataklıklar ve sürekli sulanan tarım alanlarının büyüklüğü arasında güçlü pozitif korelasyon bulunmuş olup, bu da biyolojik çeşitliliği desteklemede habitat büyüklüğünün kritik rolüne işaret etmektedir. Mevsimsel su seviyesi dalgalanmaları da delta bölgelerindeki çeşitliliği önemli ölçüde etkilemiştir. Sulak alanların küresel çapta kaybı göz önüne alındığında, bu hayatî ekosistemleri anlamak ve korumak için standart yöntemlerle uzun vadeli araştırmalar yapılması büyük önem taşıyor.

Anahtar kelimeler: Çeşitlilik indeksi, ornitofauna, sulak alan ekosistemi, korelasyon.

1. Introduction

Biodiversity is defined as the genetic, taxonomic, and ecosystem diversity of organisms in a specific area (Evans & Sheldon, 2008, Michel et al., 2020, Oliveira et al. 2019). According to this definition, species and populations serve as indicators of richness within an ecosystem. Wetlands, which constitute one of the most important ecosystems in

Corresponding author: uysalibrahim@comu.edu.tr

terms of biological diversity, provide habitat for numerous fauna and flora species (Dahl et al., 1991; Buckton, 2007; Sulaiman et al., 2015; Dauda et al., 2017; Harris, 1988; Richardson, 1994; Ghermandi et al., 2010; Gray et al, 2013; Murillo-Pacheco et al., 2018).

Therefore, wetlands are among the most important ecosystems on Earth for conserving biological diversity, sustaining ecosystem services, and managing water resources (Uysal & Uysal, 2022). However, since the beginning of the 20th century, a significant portion of wetlands worldwide has been under threat, mainly due to agricultural activities, global warming, anthropogenic pollution, and urbanization (Zedler & Kercher, 2005; Davidson, 2014; Çelik & Çelik, 2024). It is estimated that more than 50% of the total surface area of wetlands has been lost globally over the past century (Mitsch & Gosselink, 2007).

The most important group of wetland ecosystems comprises waterbirds and migratory birds. Waterbirds are highlighted as the primary vectors maintaining biotic connections between basins for aquatic plants and invertebrates and they are the organisms that respond most rapidly to changes in wetland ecosystems (Amezaga et al., 2002; Sulaiman et al., 2015). Therefore, monitoring their distributions, densities, and diversities provides information about their habitats (Sinav, 2019). Similarly, providing critical habitats such as wintering, resting, and nesting areas for migratory birds helps maintain ecosystem balance (Goudarzian & Erfanifard, 2017). In this context, studies have aimed to reveal the relationship between changes in wetland ecosystems and bird species diversity. Scientific research conducted by Arslan et al. (2023) in the Gediz Delta between 1835 and 2019 assessed changes in structure and composition based on average bird abundance using scientific studies, citizen science databases, and expert knowledge surveys. The findings indicated that changes in land cover and land use shape local bird communities. While agricultural practices have led to a decline in bird species in farmlands and grasslands, an increase in bird species diversity in coastal wetlands was observed due to effective conservation measures (Arslan et al., 2023). Nagy et al. (2022), on the other hand, utilized species distribution models to assess the exposure of waterbird species to climate change. They reported that, for most Palearctic migratory waterbird species, habitat losses in current stopover and wintering areas could largely be compensated for by newly emerging climatically suitable areas. However, they emphasized that climate change adaptation measures focusing solely on critical areas would be insufficient to offset the projected habitat losses (Nagy et al., 2022).

In order to monitor changes in wetland ecosystems, it is crucial to conduct bird species inventories and collect data using regular and standardized data collection methods. For this purpose, the comparison of monthly variations in bird species diversity in the wetland areas surrounding the Çanakkale Strait, which plays a significant role in migration strategies for numerous bird species in the northeastern Mediterranean basin, has been aimed. The study aims to test the relationship between similarity among areas, the extent of habitat types, and diversity indices by comparing monthly changes in bird species diversity across these areas.

2. Material and Method

2.1. Study Area

The research was conducted in five different wetland areas surrounding the Çanakkale Strait, which is one of the important bird migration routes in the Western Palearctic region and meets significant natural area criteria. The wetlands where the research was conducted include delta-type wetlands (Kavak Delta, Umurbey Delta, and Kumkale Delta), a lagoon-type wetland (Çardak Lagoon), and a salt lake and coastal wetland (Suvla Salt Lake). The locations of the wetland areas where the study was conducted are provided in Figure 1. Only a part of the Kavak Delta is designated as a Special Environmental Protection Area, while the remaining areas lack any protection status.

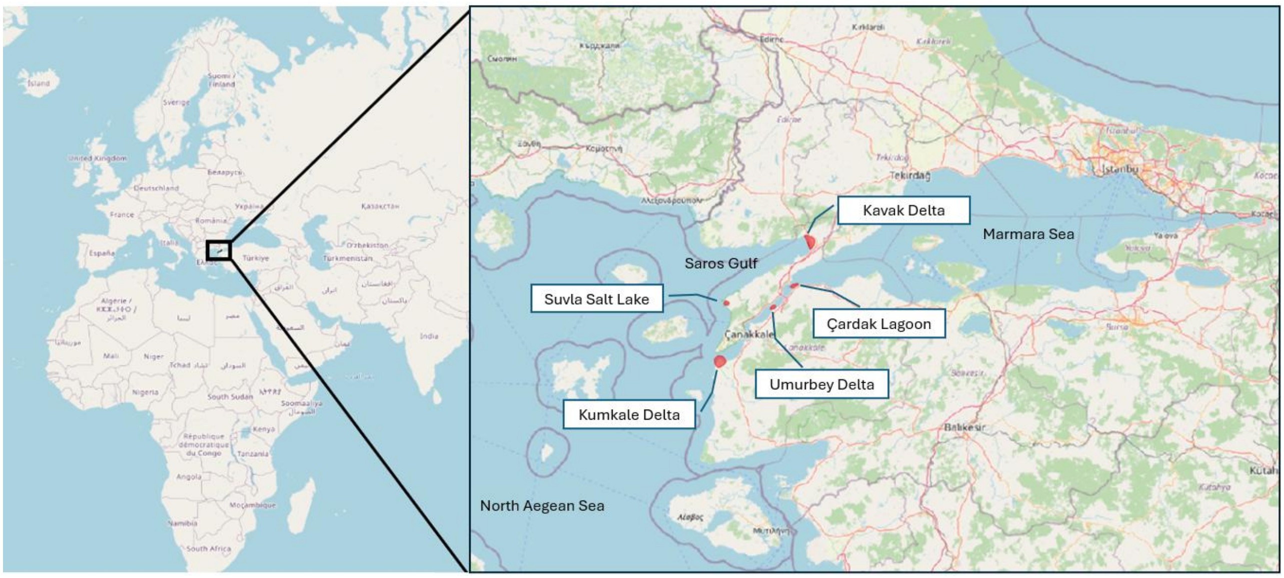

Figure 1. Locations of research sites.

Kavak Delta covers an area of approximately 5851.36 hectares and is characterized by coastal wetland features, including sandy and gravelly coastal dunes, saline and freshwater pools, and irrigated agricultural lands.

Umurbey Delta covers an area of approximately 450 hectares and is a coastal wetland area characterized by mountainous regions, plateau areas, and plains. It encompasses various habitat features such as dry and irrigated agricultural lands, water ponds, and wet meadows. Suvla Salt Lake covers an area of approximately 220 hectares. It comprises of different habitat types including saline marshes, rocky and dune areas, freshwater and brackish water bodies connected to the sea, and rocky areas in the northern part. Kumkale Delta covers an area of approximately 8.513.18 hectares. This coastal wetland area includes diverse habitat features such as dry and wet agricultural lands, saline and freshwater ponds, seasonal and temporary streams, and wet meadows. Çardak Lagoon, on the other hand, is approximately 1363.64 hectares in size and is characterized by a morphological coastal ridge and lagoon features. According to the Corine classification, the wetland areas consist of 14 different habitat types, with salt marshes being the largest habitat component. The areas covered by habitat types determined according to the Corine classification in hectares are provided in Table 1.

Table 1. Distribution and surface area (hectares/ha) of habitat types determined according to Corine classification in wetlands.

Habitat Type	Çardak Lagoon (ha)	Kumkale Delta (ha)	Kavak Delta (ha)	Umurbey Delta (ha)	Suvla Salt Lake (ha)
Total Area	1363.64	8513.18	5851.36	450	220
Salt Marshes	44.74	247.84	1185.74	90	
Non-irrigated Arable Land	38.7	2267.0	978.39	58.5	45.87
Permanently irrigated Land	-	5866.85	2842	8.80	-
Coastal Lagoons	134.99	-	3.55	206.71	
Rice Fields	-	-	60.38	-	-
Olive Groves	380.31	-	-	-	-
Complex Cultivation	79.26	-	-	-	-
Agriculture Land with Natural Vegetation	79.22	-	79.9	-	-
Coniferous Forest	252.39	-	-	-	-
Urban Fabric	102.46	-	44.89	42.33	-
Fruit Trees	290.27	-	-	144.52	-
Transitional Woodland / Shrub	14.46	-	739.96	68.6	-
Pastures	-	98.40	80.2	73.3	-
Beaches, Dunes, Sands	8.89	33.09	12.64	9.11	39.66

2.2. Sampling Method

Fieldwork was conducted in 2023 by visiting each area once a month using point count and transect observation methods as described by Bird and Bildstein (2007). Species and population counts in the areas were conducted using observation points determined to allow observation of the entire area, depending on the characteristics of the area, and the mobility level of the birds. Point count method was used for less mobile waterbirds, while transect (along a line) observation method was used for bird species with higher mobility. Conducting a perfect population count for bird species is quite challenging. This can be attributed to factors such as seasonal and daily bird movements in the areas, the dynamic nature of the area, and the hiding abilities of bird species. Therefore, data collection methods were standardized across all areas and data of sufficient size to allow statistical estimation were collected. Bird counts in all areas were initiated during the early morning hours when birds are most active for feeding and all counts were conducted by an equal number of observers to ensure equal effort in data collection. Additionally, to minimize errors in compiling bird species lists for the areas, data from other bird observers in the region were checked by consulting ebird.org and trakus.org databases and included in the research dataset.

2.3. Data Analysis

In comparing communities, it is essential to make the data obtained through standard data collection methods statistically comparable. One of the methods used for this purpose is the calculation of diversity indices. Index values are mathematical expressions of the ratio of bird species and individual numbers in an area obtained through mathematical operations (Odum & Barrett, 1971). Within the scope of the research, using the monthly counts of species and individuals obtained, diversity, species richness, and evenness indices for each area were calculated monthly. The following formulas were used: Shannon-Wiener diversity index (Shannon & Weaver, 1963) formula: $H' = -\Sigma p_i \ln(p_i)$; Margalef species richness index (Margalef, 1958) formula: $M = (S - 1) / \ln N$; Pielou index (Pielou, 1966) formula: $J = H' / H_{max} = H' / \ln S$. Additionally, to calculate similarities between areas, the Jaccard index (Jaccard, 1901) and cluster analysis were applied. The relationship between habitat types and their areas covered in wetland areas and diversity indices was analyzed using Spearman's rho correlation analysis.

3. Results

The study investigated the monthly variations of bird species lists and diversity indices, as well as the relationship with habitat types, in five wetland areas around the Çanakkale Strait, which serves as a critical resting, feeding, breeding, and wintering area along an important migration route in the Western Palearctic zoogeographic region. Fieldwork conducted monthly in five different wetland areas resulted in a total count of 184.068 birds belonging to 279 bird species, encompassing 22 orders and 61 families across all areas. Abundance was calculated considering the total number of species throughout the year in all wetland areas. Among the waterbird species dependent on wetlands, *Larus michahellis* with 6.4%, *Phoenicopterus roseus* with 4.7%, and *Tadorna ferruginea* with 2.97% were the most dominant species. The rarest species recorded only once included *Mergus merganser*, *Milvus milvus*, *Buteo lagopus*, *Grus grus*, *Pluvialis fulva, Gallinago media*, *Larus cachinnans*, *Larus armenicus*, *Clamator glandarius*, *Asio flammeus*, *Alaudala rufescens*, and *Lanius excubitor*. The most dominant species for Çardak Lagoon were *Calidris alpina* and *Larus ridibundus*; for Kumkale Delta, *Tadorna ferruginea* and *Larus michahellis*; for Kavak Delta, *Mareca penelope*, *Anas platyrhynchos*, *Calidris alpina*, and *Larus michahellis*; for Umurbey Delta, *Larus ridibundus*, *Larus michahellis*, and *Phylloscopus trochilus*; and for Suvla Salt Lake, *Phoenicopterus roseus*, *Tadorna ferruginea*, and *Tadorna tadorna* species.

3.1. Number of Species

As a result of the research, Çardak Lagoon recorded 162 species belonging to 19 orders and 44 families, Kumkale Delta recorded 234 species belonging to 22 orders and 55 families, Kavak Delta recorded 242 species belonging to 22 orders and 59 families, Umurbey Delta recorded 201 bird species belonging to 21 orders and 51 families, and Suvla Salt Lake recorded 155 bird species belonging to 20 orders and 44 families. The highest number of species observed monthly was 189 species in April at Kavak Delta, while the highest number of individuals was recorded in January with 16.842 individuals, again in Kavak Delta. The lowest number of species observed was 27 species in June at Çardak Lagoon and the lowest number of individuals was recorded in September with 247 individuals, also in Çardak Lagoon. When the counts conducted in all wetland areas were examined by month, the highest number of species was observed in April with 217 species and the highest number of individuals was counted in January with 24.100 individuals. The distributions of total species (S) and individuals (n) recorded based on monthly counts conducted in five wetland areas are presented in Table 2.

Table 2. Observed total species and individual numbers of wetlands by month.

Month	Çardak Lagoon		Kumkale Delta		Kavak Delta		Umurbey Delta		Suvla Salt Lake	
	S	N	S	n	S	n	S	n	S	n
January	89	2225	91	954	106	16842	68	1381	58	2698
February	74	3140	65	8425	91	6850	64	2515	67	2332
March	73	1591	102	1103	76	1105	102	1119	58	932
April	69	1486	160	2325	189	11986	155	5559	93	1950
May	66	617	131	4257	142	3480	125	1842	73	2083
June	27	776	50	418	76	696	73	730	40	666
July	52	848	73	479	59	1177	91	1329	49	1024
August	49	480	126	1792	149	6440	118	1689	53	493
September	47	247	136	3296	169	9668	120	2243	54	1974
October	33	378	130	2819	162	16801	97	1531	36	1175
November	91	2739	86	1019	113	7370	82	1157	31	719
December	71	2594	93	1570	105	11919	86	1273	73	5742
TOTAL	162	17121	234	28457	242	94334	201	22368	155	21788

*S: Total Number of Species, n: Total Number of Individuals

According to the criteria of the International Union for Conservation of Nature (IUCN) Red List, Version 2023/2 (International Union for Conservation of Nature, 2023), among the bird species identified, one species (*Stercorarius parasiticus*) is classified as Endangered at the European scale, 18 species are categorized as Vulnerable, indicating a high risk of extinction in the wild, and nine species are classified as Near Threatened, indicating potential future endangerment. These species belong to 14 orders and 20 families. At the order level, 39% of species in the endangered category belong to the Charadriiformes order and 16% belong to the Anseriformes order. Shallow water birds are species observed in river deltas, estuaries, lagoons, nearshore freshwater habitats, and the sea, being dependent on wetlands for part of their life cycles. These birds can be classified as flamingos, swans, geese, ducks, grebes, pelicans, herons, gulls, and terns. Of the species recorded and classified in the endangered category within the scope of the study, 81.6% are waterbird species. Lists of species endangered at the European and global scales according to IUCN Red List criteria and their regional statuses based on wetland areas are provided in Table 3.

3.2. Diversity Indexes

Within the scope of the study, the total number of species and individuals recorded in the wetland areas over one year was evaluated along with species richness, diversity, and evenness of species distribution. Diversity indices graphics in wetlands are given Figure 2. The Margalef index represents species richness, varying depending on the number of species and has no limit value. The area with the highest species richness in the study was Kumkale Delta (D: 22.718). The number of species in an area is directly related to habitat diversity and Kumkale Delta recorded the highest number of habitat types among the wetland areas surveyed. The Shannon-Wiener Index (H') represents species diversity and as the value increases, the diversity of species in the area also increases. The index generally ranges between 0 and 5. Among the study areas, Kavak Delta exhibited the highest species diversity (H': 2.416). The Pielou Index provides information about the balance of species distribution, ranging from 0 to 1, with a value close to 1 indicating a balanced distribution among species within the community. Across all the wetland areas surveyed in the study, values ranged from 0.357 to 0.466 based on the total observation data collected over one year.

Table 3. List of endangered bird species detected in wetlands according to IUCN Red List criteria (v.2023/2).

Species	Common Name	IUCN (Europe)	IUCN (Global)	Kumkale Delta	Kavak Delta	Çardak Lagoon	Umurbey Delta	Suvla Salt Lake
Podiceps auritus	Horned Grebe	NT	VU	-	Wv	Wv	-	-
Podiceps nigricollis	Black-necked Grebe	VU	LC	Wv, r	Wv	Wv	Wv	Wv
Pelecanus crispus	Dalmatian Pelican	LC	NT	T	Wv	T	T	Wv
Puffinus yelkouan	Yelkouan Shearwater	VU	VU	T	T	T	T	T
Cygnus columbianus	Tundra Swan	VU	LC	-	Wv	-	-	-
Aythya ferina	Common Pochard	VU	VU	Wv	Wv,t	Wv	Wv	-
Aythya nyroca	Ferruginous Duck	LC	NT	Wv, r	Wv	Wv	Wv	-
Aythya fuligula	Tufted Duck	NT	LC	T	Wv,t	-	T	-
Mergus serrator	Red-breasted Merganser	NT	LC	-	Wv	Wv	-	Wv
Oxyura leucocephala	White-headed Duck	VU	EN	T	-	-	T	-
Circus macrourus	Pallid Harrier	LC	NT	T	T	-	T	T
Falco vespertinus	Red-footed Falcon	VU	VU	T	T	-	T	-
Falco columbarius	Merlin	VU	LC	Wv	Wv	Wv	-	Wv
Coturnix coturnix	Common Quail	NT	LC	T	T	-	T	-
Fulica atra	Common Coot	NT	LC	R, Wv	Wv	Wv	R, Wv	T
Tetrax tetrax	Little Bustard	VU	NT	T	Wv	-	-	-
Haematopus ostralegus	Eurasian Oystercatcher	VU	NT	T	T,yz	Sv	T	T
Vanellus vanellus	Northern Lapwing	VU	NT	Wv	Wv	T	T	T
Calidris canutus	Red Knot	LC	NT	T	T	T	-	-
Calidris ferruginea	Curlew Sandpiper	VU	NT	T	T	T	T	T
Limicola falcinellus	Broad-billed Sandpiper	VU	LC	T	T	T	T	T
Philomachus pugnax	Ruff	NT	LC	T	Wv,t	T	T	T
Gallinago gallinago	Common Snipe	VU	LC	Wv	Wv	Wv	Wv	Wv
Limosa limosa	Black-tailed Godwit	NT	NT	T	T	-	T	-
Limosa lapponica	Bar-tailed Godwit	LC	NT	T	T	-		
Numenius arquata	Eurasian Curlew	NT	NT	Wv	Wv	Wv	Wv	Wv
Tringa totanus	Common Redshank	VU	LC	R	R	R	R	R
Stercorarius parasiticus	Arctic Jaeger	EN	LC	-	T	-	-	-
Chroicocephalus genei	Slender-billed Gull	VU	LC	Wv	Wv	Wv	Wv	Wv
Ichthyaetus audouinii	Audouin's Gull	VU	VU	Wv	Wv	-	-	Wv
Streptopelia turtur	European Turtle-dove	VU	VU	Sv	T	T	T	-
Lanius senator	Woodchat Shrike	NT	NT	Sv	-	Sv	Sv	Sv
Apus apus	Common Swift	LC	NT	T	T	T	-	-
Corvus frugilegus	Rook	VU	LC	T	-	-	-	-
Turdus iliacus	Redwing	LC	NT	-	Wv	-	-	-

In the wetland areas where the study was conducted, the highest species diversity (Shannon-Wiener Indices) was observed in May (H': 2.659) in Kavak Delta, while species richness (Margalef Index) was recorded in April (M: 20.512) in Kumkale Delta. Species richness values were found to increase during the spring migration period (April, May, June) and the autumn migration period (September, October) in Kavak Delta, Kumkale Delta, and Umurbey Delta. In Suvla Salt Lake, species richness increases during the spring migration period (March, April) and winter period (December, February), while in Çardak Lagoon, it increases during the spring migration period and winter period (May, November, January). The lowest species richness values were calculated in July, the breeding season, across all areas. Monthly variations in species richness are given Figure 3.

Diversity indices are quantitative measures reflecting the number of different species and how evenly individuals are distributed among these species. Typically, the value of a diversity index increases as the number of species and evenness increase. For instance, communities where numerous species are evenly distributed are considered the most diverse, while those with fewer species and dominance of a single species are considered the least diverse. Although a decrease in diversity was observed in August in Kavak Delta and in June in Kumkale Delta, these periods coincide with the breeding season for bird species. In Kumkale Delta, the lowest diversity across all areas was recorded in February, likely due to the dominance of a single species, the starling (*Sturnus vulgaris*), which accounted for 8000 individuals recorded in the area. Monthly variations in species diversity are given Figure 4.

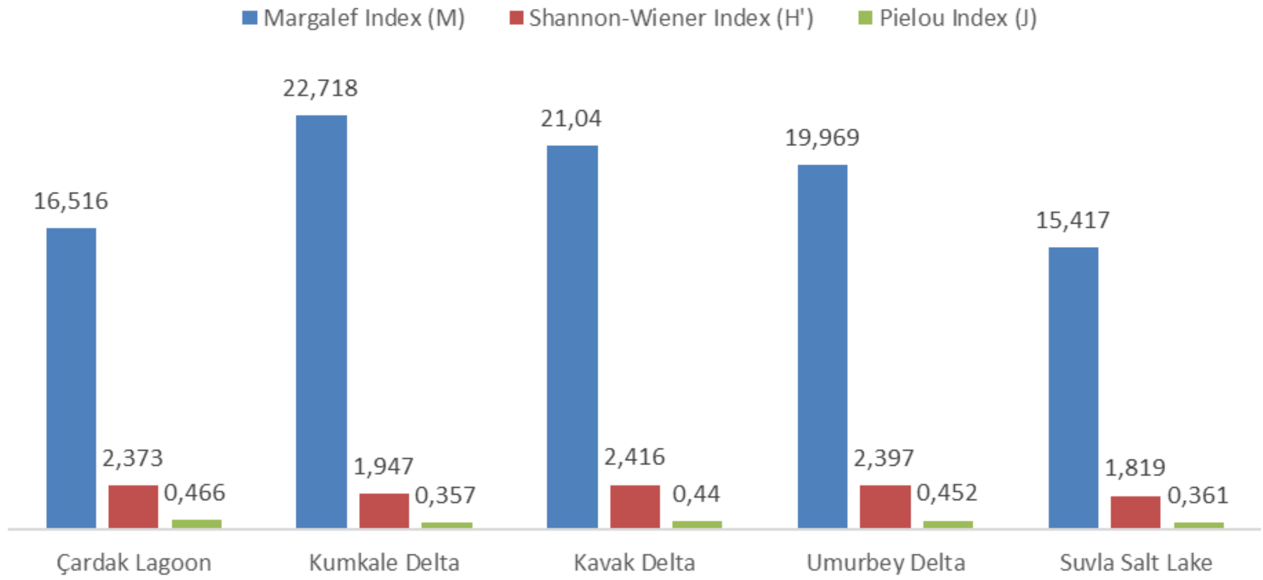

Figure 2. Diversity indices in wetlands.

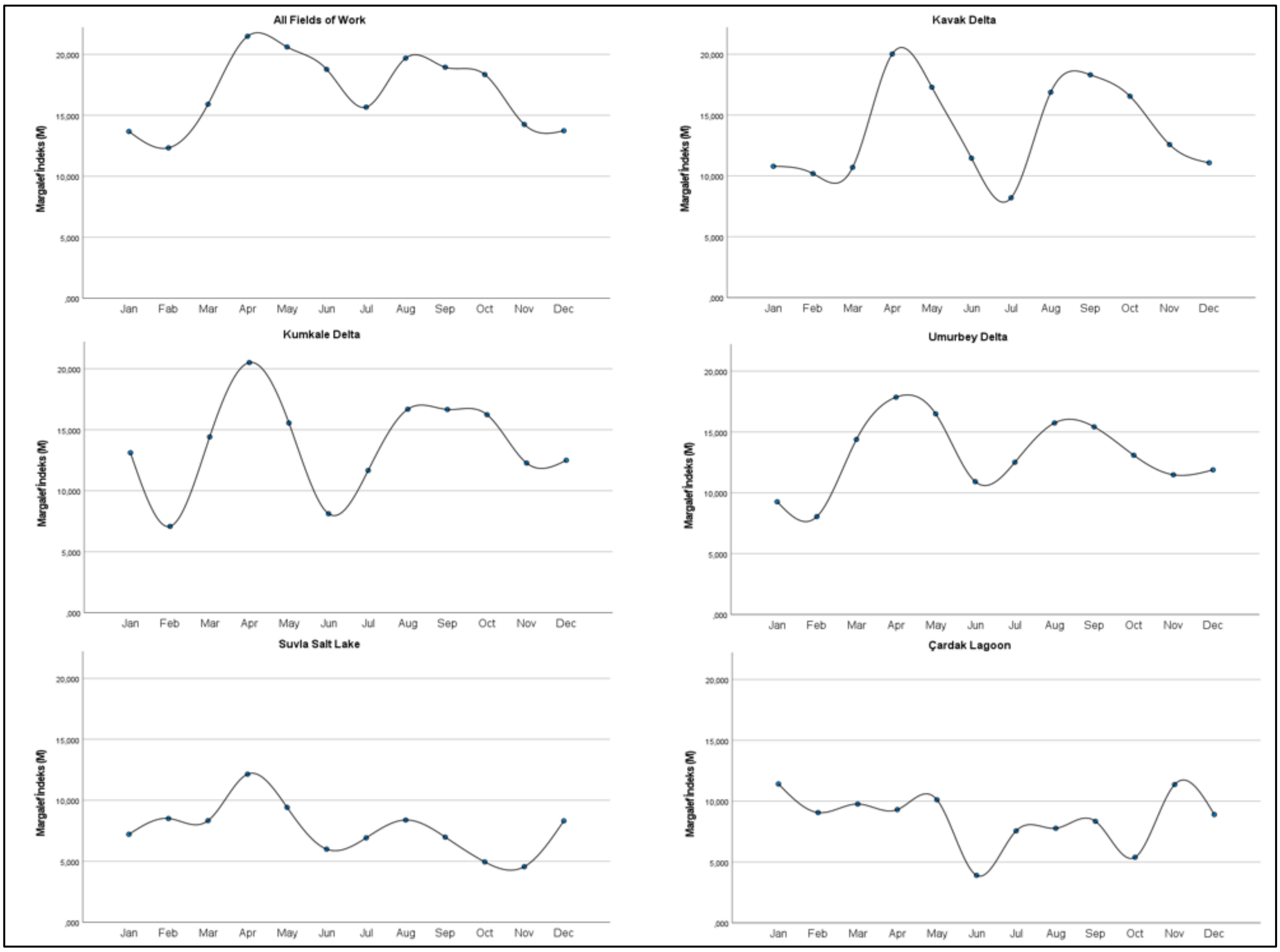

Figure 3. Monthly variations in species richness (Margalef Index).

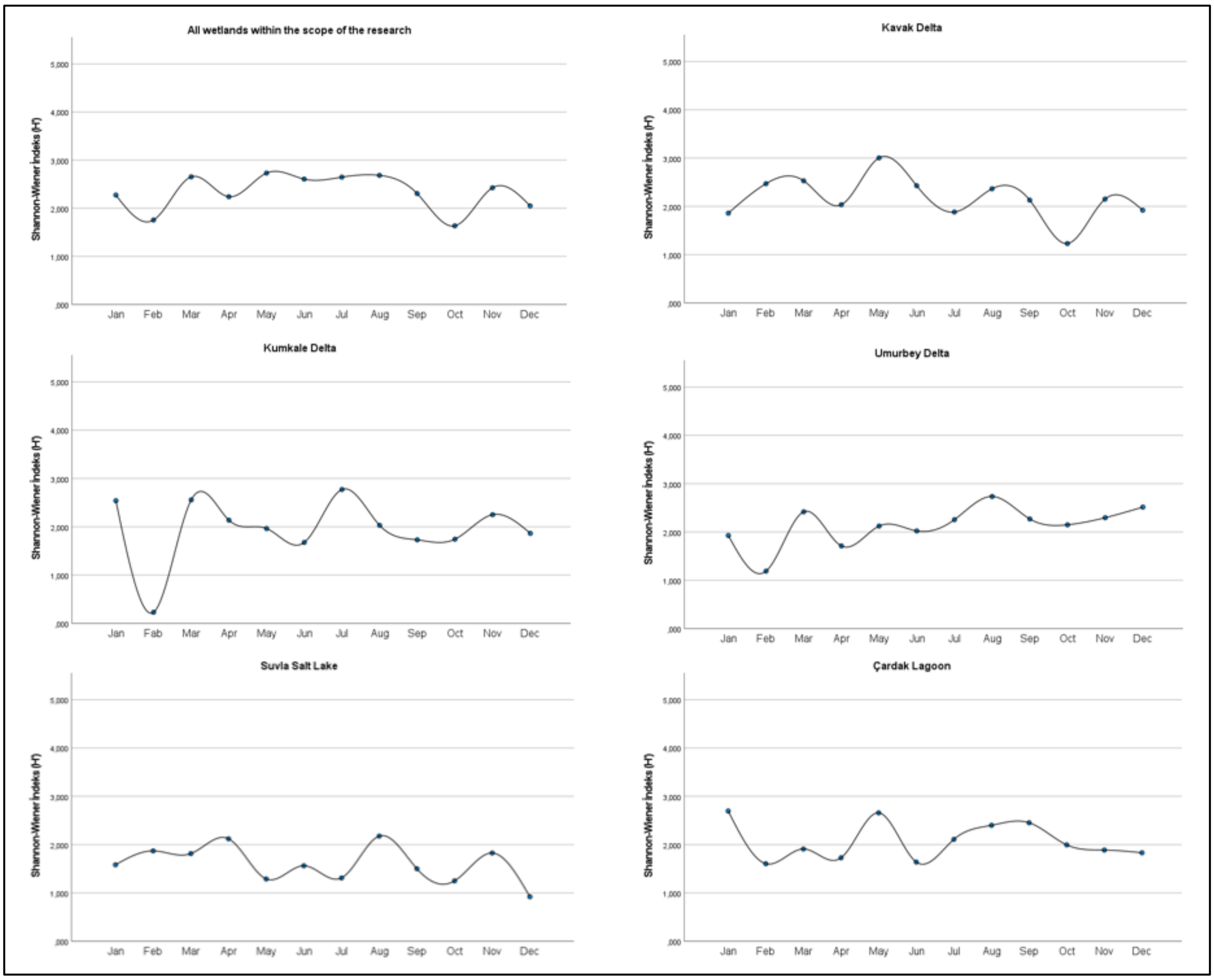

Figure 4. Monthly variations in species diversity (Shannon-Wiener Indices).

3.3. Similarity Index

The dendrogram resulting from the hierarchical clustering analysis based on species compositions in the wetlands is presented in Figure 5. The dendrogram illustrates the relationships between wetlands in terms of their similarity and distance, forming clusters. It can be observed that Kumkale Delta and Kavak Delta are the most similar wetlands, forming a cluster with Umurbey Delta, while Çardak Lagoon and Suvla Salt Lake, although less similar to each other, form a separate cluster. Hierarchical cluster analysis dendrogram are given Figure 5.

3.4. Correlation Analysis Results

According to the results of the Spearman's rho correlation analysis conducted to examine the relationship between species lists of wetland areas, the total recorded abundance of individuals, calculated diversity indices, and the sizes (hectares) of habitat types present in the wetlands, the following correlations were observed: Species richness (Margalef Index) showed a strong positive correlation with the total size of the wetland area as well as the sizes of salt marshes, permanently irrigated land, and pasture areas. Species diversity (Shannon-Wiener index) exhibited a strong positive correlation with the size of Transitional Woodland/Shrub habitats. The Pielou index revealed a strong negative correlation with the size of beaches, dunes, and sands habitats. Correlation between diversity indices and wetland habitat types are given Table 4.

4. Discussion

In the monthly counts conducted in the wetland areas within the scope of the research, the highest number of species was observed in April with 92 species, while the highest number of individuals, totaling 10.991 individuals, was observed in January. Fieldwork conducted once a month in five different wetland areas resulted in a total count of 184.068 birds belonging to 279 bird species within 22 orders and 61 families across all areas. Standard data collection methods should be used for comparing communities and the obtained data should be made statistically comparable. One of the methods used for this purpose is the calculation of diversity indices. In the study conducted by Uysal and Uysal (2021), investigating the monthly diversity indices of waterbirds in Suvla Salt Lake, it was found that the highest species diversity was in February (H': 2.377). Similarly, in the present study, the highest species diversity (H': 1.871) was observed in February, although the diversity index showed a declining trend. In a study conducted by Dauda et al. (2017) in the Ramsar site Uchali wetland in Pakistan, comparisons were made with previous studies conducted in the area, revealing that the number of bird species supported by the wetland area was significantly lower in the recent past (1991) compared to the number of bird species supported by the same wetland area. When evaluated together with previous studies conducted in the same area, it was found that there was an annual decrease of 6.59 species. The study conducted in the wetland areas surrounding the

Çanakkale Strait, which forms one of the important bird migration routes in the Mediterranean basin, provides data for future monitoring studies. These data along this important migration route can provide insights into the changes in bird species diversity across a wide region.

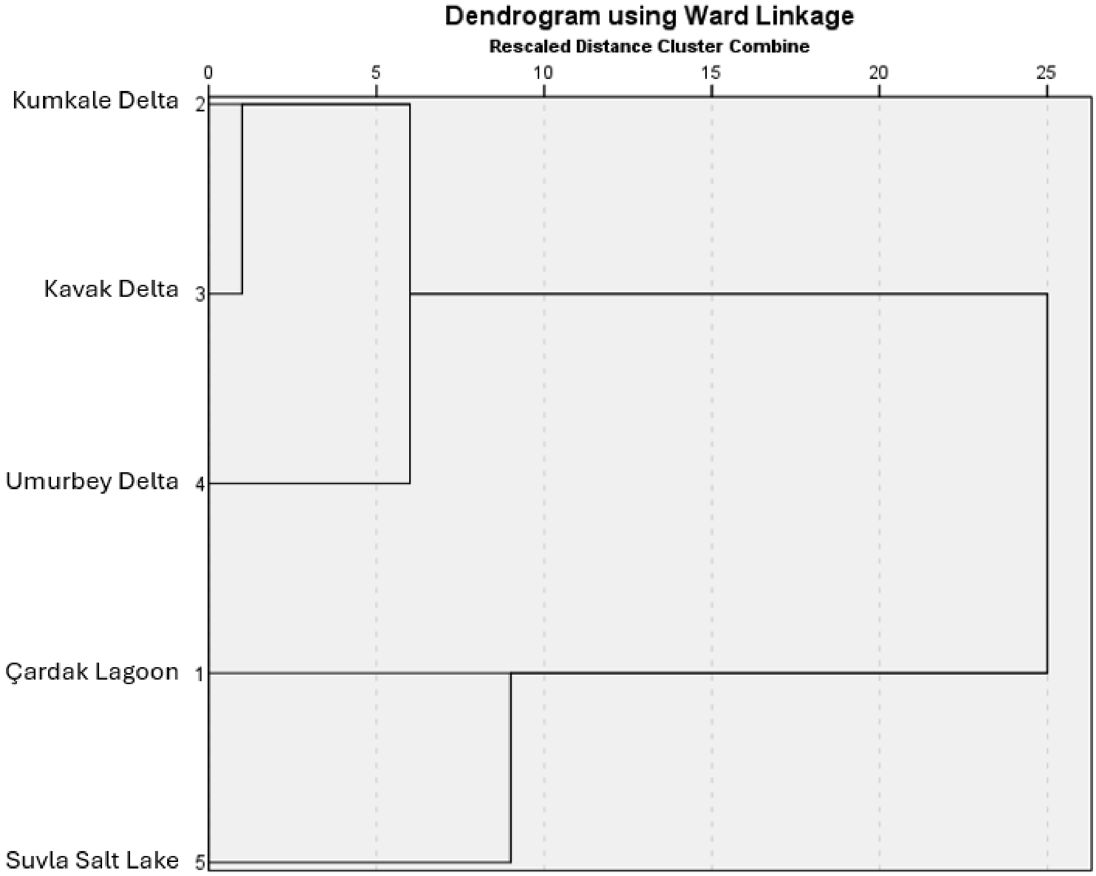

Figure 5. Hierarchical cluster analysis dendrogram.

Table 4. Correlation between diversity indices and wetland habitat types.

Habitat size (hectare)	Margalef Index (M)	Shannon -Wiener Index (H')	Pielou Index (J)
Total Area	**.900***	.300	-.300
Salt Marshes	**.900***	.700	-.200
Non-irrigated Arable Land	**.900**	.200	-.700
Permanently irrigated Land	**.975****	.308	-.564
Coastal Lagoons	-.103	.667	.872
Rice Fields	.354	.707	.000
Olive Groves	-.354	.000	.707
Complex Cultivation	-.354	.000	.707
Agriculture Land with Natural Vegetation	.112	.671	.447
Coniferous Forest	-.354	.000	.707
Urban Fabric	-.103	.667	.872
Fruit Trees	-.335	.224	.894
Transitional Woodland / Shrub	.205	**.975****	.564
Pastures	**.975****	.308	-.564
Beaches, Dunes, Sands	.000	-.600	**-.900***

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

To highlight the adverse effects of wetland losses on biodiversity and sustainability at a global scale, there is a need for model organisms. Bird species are living organisms capable of quickly responding to sudden and adverse changes in their habitats and they provide significant ecosystem services. With their ability to rapidly relocate in response to environmental changes, bird species can serve as indicator species and model organisms for monitoring the sustainable and healthy structure of ecosystems, unlike other animal groups.

To be able to compare different wetland areas and track changes in their ecosystems, it is necessary to make an inventory of species and conduct regular counts. The effects of global warming and increasing anthropogenic pressures around wetlands, such as disturbances in the water regime and wetland losses, are accelerating the extinction rate of some species, which are vital components of these ecosystems. In recent years, researchers' trends towards assessing and conserving biological diversity draw attention to this issue (Guo et al., 2003). The combined effects of land-use changes and climate change lead to biodiversity loss, community homogenization, and a decline in ecosystem functioning (Sekercioglu et al. 2008; Newbold et al., 2019; Rastandeh & Pedersen, 2018; Zhao et al., 2016; Northrup et al., 2019; Bateman et al. 2020). The Çanakkale Strait, located in the northeastern part of the Mediterranean basin, serves as an important migration corridor for numerous bird species. This underscores the ornithological importance of the wetlands surrounding the Çanakkale Strait. Diversity and similarity indices enable the standardization of data for comparing bird communities across different areas. Within the scope of this study, monthly variations in bird species diversity in the wetlands around the Çanakkale Strait were investigated. Additionally, correlations between the habitat types and areas of these wetlands and their diversity indices were analyzed and updated species lists for the studied wetlands were compiled.

In previous studies conducted in the wetland areas where the research was carried out, there were no data available on bird species lists. However, with the current study, updated bird species lists have been compiled. In the study conducted by Özcan et al. (2009) in Kavak Delta, between 2005 and 2007, 130 bird species belonging to 14 orders and 40 families were listed. Through monthly counts and bird observation data collected regularly within the scope of the research, the distribution of 242 species belonging to 22 orders and 59 families was determined in Kavak Delta. In the postgraduate thesis study conducted by Samsa (2012) in Çardak Lagoon between 2008 and 2011, 102 species belonging to 15 orders and 35 families were identified. In the research conducted, 162 species belonging to 19 orders and 44 families were identified in Çardak Lagoon. In the postgraduate thesis study conducted by Şengül (2012) in Kumkale Delta between 2011 and 2012, 120 bird species belonging to 14 orders and 39 families were identified. However, in the research, 234 bird species belonging to 22 orders and 55 families were identified in Kumkale Delta. In the study conducted by Uyman and Tosunoğlu (2019) in Umurbey Delta, 182 bird species belonging to 20 orders and 49 families were recorded. However, in the research, 201 bird species belonging to 21 orders and 51 families were identified in Umurbey Delta. In the study conducted by Uysal and Uysal (2021) in Suvla Salt Lake, 154 bird species belonging to 20 orders and 44 families were identified through monthly observations between 2017-2020. However, in the research completed with monthly counts in 2023, 155 bird species belonging to 20 orders and 44 families were recorded in Suvla Salt Lake. The increase in species numbers observed in the current study compared to the previous studies is believed to be related not to the increase in bird species diversity in the area but rather to the regular monthly observations conducted in the field. Globally, the decline in population sizes and ranges of numerous species continues rapidly. In recent years, observed changes in the distribution of many species are primarily attributed to ongoing rapid climate change and large-scale habitat loss (Sekercioglu et al. 2008; Davidson, 2014; Northrup et al., 2019). Additionally, there is a northward shift in the distribution of waterbird species due to the impact of global warming (Hickling et al., 2006; Chen & Zhou, 2011). On the other hand, the increase in species numbers observed in the study areas compared to the previous literature data is thought to be associated with the standard observation methodology, namely, the conduct of monthly fieldwork and the increase in the number of bird observers, paralleled by the increase in data entered into national and international databases within the scope of citizen science.

It is noted that the relationship between wetlands and bird species is bidirectional, with wetlands playing an important role in shaping the richness of bird species (Skórka et al., 2006). The decrease in the number of bird species in wetlands can be attributed to fluctuations in the surface area and water level of the wetland. Studies in this regard have shown a positive relationship between the abundance of bird species and the water level of wetlands (Maclean et al., 2011; Sharma & Saini, 2012). Additionally, habitat diversity in wetlands is also associated with bird species diversity (Uysal & Uysal, 2022). Similarly, the sudden decrease in species diversity in wetlands is mainly attributed to habitat changes (Azizoğlu et al., 2023; Reif & Flousek, 2012; González & Farina, 2013; Russell et al., 2014). Among the 5 wetland areas where data was collected in the study, Çardak Lagoon stands out in terms of similarity as it is connected to the sea through the lagoon mouth and maintains water levels throughout the year. The species composition and diversity indices in these areas did not show significant differences compared to the other areas throughout the year. In Deltas where shallow surface waters are more abundant, there were more pronounced differences in diversity indices due to seasonal variations in water levels. In the study, a strong positive relationship was found between species richness (Margalef Index) and the total size of the wetland, salt marshes, permanently irrigated land, and pasture areas.

In all wetland areas where the research was conducted, the breeding seasons were found to be the periods with the lowest species diversity and richness. Pearce-Higgins et al. (2015) noted in their study in the UK that there were changes among important species groups during the breeding season (especially in June), winter (December- February), and summer (July and August) periods and that cold winters had a consistent negative impact on resident and short-distance migrant bird populations in the UK on a large scale. They mentioned that the populations of long-distance migrants were not affected by winter temperatures throughout the year but were strongly associated with rainfall in their wintering areas. Being located on an important migration route increases species diversity and richness during migration periods in our study area, while during the winter period, with species coming to winter from further north, species diversity and richness increase. However, due to the impact of global warming, there has been a northward shift in the distribution of waterbird species (Hickling et al., 2006; Chen & Zhou, 2011) and since the early 20th century, a large part of wetlands worldwide has become the most threatened habitats due to the factors such as agricultural activities, global warming, anthropogenic pollution, and urbanization (Zedler & Kercher, 2005; Davidson, 2014).

The dendrogram derived from the hierarchical clustering analysis based on species compositions in the wetlands indicates that the Kumkale Delta and Kavak Delta exhibit the highest similarity, clustering together with the Umurbey Delta. In contrast, the Çardak Lagoon and Suvla Salt Lake, despite being less similar to each other, form a distinct cluster. Typically, in wetlands where the water table is close to the surface, the terrain is covered with shallow waters, water sources feeding the wetland are small, and the water level changes more rapidly seasonally or depending on temperatures. This rapid fluctuation in water level leads to faster changes in bird species populations within the wetland. Despite not being fed by freshwater sources in terms of wetland type, Çardak Lagoon and Suvla Salt Lake, due to their connection to the sea, relatively maintain their water levels and cover a larger area of saline and brackish water compared to other more deltaic wetlands. The differences in species compositions and diversity indices in these areas compared to other wetlands, and their relatively stable changes throughout the year, can be explained by this situation.

5. Conclusions

The study underscores the importance of standardized bird species monitoring to track ecosystem changes, particularly in the Çanakkale/Dardanelles Strait, a key migratory route in the Mediterranean. According to Kiziroğlu (2015), the number of bird species recorded in Turkey is 513. 54.5% of the bird species recorded in Turkey were observed in the wetlands where the study was conducted. This situation points to the ornithological importance of the Dardanelles and the surrounding wetlands, which are on an important migration route. Observing 279 species across 22 orders and 61 families, the research reveals high species richness and diversity, especially during migration periods. A strong positive correlation was found between species richness and the size of wetlands, particularly salt marshes and permanently irrigated lands, indicating the critical role of habitat size in supporting biodiversity. Seasonal water level fluctuations also significantly impacted diversity in delta regions. Given the global loss of wetlands, long-term research with standardized methods is crucial for understanding and protecting these vital ecosystems.

Ethics committee approval: Ethics committee approval is not required for this study.

Conflict of interest: The authors declare that there is no conflict of interest.

Author Contributions: Conception – İ.U., M.T.; Design – İ.U.; Supervision – İ.U., M.T.; Data Collection and Processing – İ.U., D.K., C.N.Ö., M.T.; Analysis Interpretation – İ.U., D.K., C.N.Ö.; Literature Review – – İ.U., D.K., C.N.Ö.; Writing – – İ.U., D.K., C.N.Ö., M.T.; Critical Review – – İ.U., D.K.

References

Amezaga, J.M., Santamaría, L., & Green, A.J. (2002). Biotic wetland connectivity—supporting a new approach for wetland policy. *Acta oecologica*, 23(3), 213-222. https://doi.org/10.1016/S1146-609X(02)01152-9.

Arslan, D., Ernoul, L., Béchet, A., Döndüren, Ö., Siki, M., & Galewski, T. (2023). Using literature and expert knowledge to determine changes in the bird community over a century in a Turkish wetland. *Marine and Freshwater Research*, 74(3), 220–233. https://doi.org/10.1071/MF21332.

Azizoglu, E., Kara, R., & Celik, E. (2023). A statistical approach on distribution and seasonal habitat use of waterfowl and shorebirds in Çıldır Lake (Ardahan, Türkiye). *Environmental Science and Pollution Research*, 30(31), 77371-77384.

Bateman, B.L., Taylor, L., Wilsey, C., Wu, J., LeBaron, G.S., & Langham, G. (2020). Risk to North American birds from climate change-related threats. *Conservation Science and Practice*, 2(8), e243.

Bird, D.M. & Bildstein, K.L. (2007). Raptor Research and Management Techniques. Hancock House Publisher. Surrey, Canada.

Buckton, S. (2007). Managing wetlands for sustainable livelihoods at Koshi Tappu. *Danphe*, 16(1), 12-13.

Chen, J., & Zhou, L. (2011). Guild structure of wintering waterbird assemblages in shallow lakes along Yangtze River in Anhui Province, China. *Shengtai Xuebao/Acta Ecologica Sinica*, 31(18), 5323-5331.

Çelik, M. A., & Çelik, E. (2024). Are Urbanisation and Biodiversity Antithetical? A Bibliometric Analysis. *Coğrafya Dergisi*, (48), 121-135.

Dahl, T.E., Johnson, C.E. & Frayer, W.E. (1991). Wetlands, status and trends in the conterminous United States mid-1970's to mid-1980's. US Fish and Wildlife Service.

Dauda, T.O., Baksh, M.H., & Shahrul, A.M.S. (2017). Birds' species diversity measurement of Uchali Wetland (Ramsar site) Pakistan. *Journal of Asia-Pacific Biodiversity*, 10(2), 167-174. https://doi.org/10.1016/j.japb.2016.06.011

Davidson, N.C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research*, 65(10), 934-941. https://doi.org/10.1071/MF14173

Evans, S.R., & Sheldon, B.C. (2008). Interspecific patterns of genetic diversity in birds: correlations with extinction risk. *Conservation Biology*, *22*(4), 1016-1025.

Ghermandi, A., Van Den Bergh, J.C., Brander, L.M., De Groot, H.L., & Nunes, P.A. (2010). Values of natural and human-made wetlands: A meta-analysis. *Water Resources Research*, 46(12). https://doi.org/10.1029/2010WR009071

González, A.L., & Fariña, J.M. (2013). Changes in the abundance and distribution of black-necked swans (*Cygnus melancoryphus*) in the Carlos Anwandter Nature Sanctuary and Adjacent Wetlands, Valdivia, Chile. *WATERBIRDS: The International Journal of Waterbird Biology*, 36(04), 507-514. http://www.bioone.org/doi/full/10.1675/063.036.0408

Goudarzian, P., & Erfanifard, S.Y. (2017). The efficiency of indices of richness, evenness and biodiversity in the investigation of species diversity changes (case study: migratory water birds of Parishan international wetland, Fars province, Iran). *Biodiversity International Journal*, 1(2), 41-45. https://doi.org/10.15406/bij.2017.01.00007

Gray, M.J., Hagy, H.M., Nyman, J.A., & Stafford, J.D. (2013). Management of wetlands for wildlife. In: Anderson MG, Davis CA (eds) *Wetland techniques: Volume 3: Applications and management*. Springer, Dordrecht, 121–180.

Guo, Y., Gong, P., & Amundson, R. (2003). Pedodiversity in the United States of America. *Geoderma*, 117(1-2), 99-115. https://doi.org/10.1016/S0016-7061(03)00137-X.

Harris, L.D. (1988). The nature of cumulative impacts on biotic diversity of wetland vertebrates. *Environmental Management*, 12, 675-693. https://doi.org/10.1007/BF01867545.

Hickling, R., Roy, D.B., Hill, J.K., Fox, R., & Thomas, C.D. (2006). The distributions of a wide range of taxonomic groups are expanding polewards. *Global change biology*, 12(3), 450-455. https://doi.org/10.1111/j.1365-2486.2006.01116.x.

International Union for Conservation of Nature (2023). The IUCN Red List of Threatened Species. Version 2023-2. Retrieved from https://www.iucnredlist.org.

Jaccard, P. (1901). Etude comparative de la distribution florale dans une portion des Alpes et du Jura. *Bulletin de la Soci´et´e Vaudoise des Sciences Naturelles*, 37(1), 547–579.

Kiziroğlu, İ. (2015). Türkiye Kuşları Cep Kitabı (The pocket book for birds of Turkey). İnkılap Kitabevi. Ankara, Türkiye.

Maclean, I.M., Wilson, R.J., & Hassall, M. (2011). Predicting changes in the abundance of African wetland birds by incorporating abundance–occupancy relationships into habitat association models. *Diversity and Distributions*, 17(3), 480-490. https://doi.org/10.1111/j.1472-4642.2011.00756.x.

Michel, N.L., Whelan, C.J., & Verutes, G.M. (2020). Ecosystem services provided by Neotropical birds. *The Condor*, 122(3).

Mitsch, W.J. & Gosselink, J.G. (2007). Wetland ecosystems Wilet J. & Sons Ed., New York, 4th ed, pp. 256.

Murillo-Pacheco, J., López-Iborra, G.M., Escobar, F., Bonilla-Rojas, W.F., & Verdú, J.R. (2018). The value of small, natural and man-made wetlands for bird diversity in the east Colombian Piedmont. *Aquatic Conservation, Marine and Freshwater Ecosystems*, 28(1), 87-97. https://doi.org/10.1002/aqc.2835.

Nagy, S., Breiner F.T., Anand, M., F. T. Breıner, S. H. M. Butchart, E. Fluet-Chouınard, M. Flörke, A. Guısan, L. Hılarıdes, et al. 2022. Climate change exposure of waterbird species in the African-Eurasian flyways. Bird Conservation International. 2022, 32(1), 1-26. doi: https://doi.org/10.1017/S0959270921000150

Newbold, T., Adams, G.L., Robles, G.A., Boakes, E.H., Ferreira, G.B., Chapman, A.S., Outhwaite, C.L. (2019). Climate and land-use change homogenise terrestrial biodiversity, with consequences for ecosystem functioning and human well-being. *Emerging Topics in Life Sciences*, 3, 207–219.

Odum, E.P. & Barrett, G.W. (1971). Fundamentals of ecology. Saunders Philadelphia.

Oliveira, J.D., Almeida, S.M., Florencio, F.P., Pinho, J.B., Oliveira, D.M., Ligeiro, R., & Rodrigues, D.J. (2019). Environmental structure affects taxonomic diversity but not functional structure of understory birds in the southwestern Brazilian Amazon. *Acta Amazonica*, 49, 232-241.

Özcan, H., Akbulak, C., Kelkit, A., Tosunoğlu, M., & İsmet, U. (2009). Ecotourism potential and management of kavak delta (northwest turkey). *Journal of Coastal Research*, 25(3), 781-787. https://doi.org/10.2112/08-1068.1.

Pearce-Higgins, J.W., Eglington, S.M., Martay, B., & Chamberlain, D.E. (2015). Drivers of climate change impacts on bird communities. *Journal of Animal Ecology*, 84(4), 943-954. https://doi.org/10.1111/1365-2656.12364.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, 13, 131-144.

Rastandeh, A., & Pedersen, Z.M. (2018). A spatial analysis of land cover patterns and its implications for urban avifauna persistence under climate change. *Landscape Ecology*, 33, 455–474.

Reif, J., & Flousek, J. (2012). The role of species' ecological traits in climatically driven altitudinal range shifts of central European birds. *Oikos*, 121(7), 1053-1060. https://doi.org/10.1111/j.1600-0706.2011.20008.x.

Richardson, C.J. (1994). Ecological functions and human values in wetlands: a framework for assessing forestry impacts. *Wetlands*, 14, 1-9. https://doi.org/10.1007/BF03160616.

Russell, I.A., Randall, R.M., & Hanekom, N. (2014). Spatial and temporal patterns of waterbird assemblages in the Wilderness Lakes Complex, South Africa. *WATERBIRDS: The International Journal of Waterbird Biology*, 1-18. https://doi.org/10.1675/063.037.0104.

Samsa, Ş. (2012). Çardak (Çanakkale/Türkiye) Lagünü Avifaunası (309626). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Shannon, C.E. & Weaver, W. (1963). The Mathematical Theory of Communication, Urbana, University of Illinois Press, Urbana, USA, pp. 117.

Sharma, K.K., & Saini, M. (2012). Impact of anthropogenic pressure on habitat utilization by the waterbirds in Gharana Wetland (reserve), Jammu (J&K, India). *International Journal of Environmental Sciences*, 2(4), 2050-2062.

Sinav, L. (2019). Türkiye'deki Kuş Türü Zenginliğinin Coğrafi Varyasyon Deseni (589924). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Skórka, P., Martyka, R., & Wójcik, J.D. (2006). Species richness of breeding birds at a landscape scale: which habitat type is the most important? *Acta Ornithologica*, 41(1), 49-54. https://doi.org/10.3161/068.041.0111.

Sulaiman, I.M., Abubakar, M.M., Ringim, A.S., Apeverga, P.T., & Dikwa, M.A. (2015). Effects of wetlands type and size on bird diversity and abundance at the Hadejia-Nguru wetlands, Nigeria. *International Journal of Research Studies in Zoology*, 1(1), 15-21.

Margalef, R. (1958). Information theory in ecology. *General Systems*, 3, 36-71.

Northrup, J.M., Rivers, J.W., Yang, Z., & Betts, M.G. (2019). Synergistic effects of climate and land-use change influence broad-scale avian population declines. *Global Change Biology*, 25, 1561–1575.

Sekercioglu, C. H., Schneider, S. H., Fay, J. P., & Loarie, S. R. (2008). Climate change, elevational range shifts, and bird extinctions. *Conservation Biology*, 22, 140–150.

Şengül, E. (2012). Kumkale Deltası' nın Avifaunası (326628). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Uyman, M., & Tosunoğlu, M. (2019). Diversity of Bird Species in Umurbey Delta (Çanakkale/Turkey). 1st International Symposium on Biodiversity Research, Çanakkale, Turkey, 2–4 May 2019. pp. 342-355.

Uysal, İ., & Uysal, İ. (2021). Suvla Tuz Gölü (Çanakkale/Türkiye)'nün Ornithofaunası ve Su Kuşları Çeşitlilik Göstergeleri'nin Aylık Değişimi. *Environmental Toxicology and Ecology*, 1(1), 14-26.

Uysal, İ., & Uysal, İ. (2022). Evaluation of different wetland preferences of wintering waterbird species in Çanakkale, Turkey. *Turkish Journal of Biodiversity*, 5(1), 17-29. https://doi.org/10.38059/biodiversity.1034415

Zhao, Q., Silverman, E., Fleming, K., & Boomer, G. S. (2016). Forecasting waterfowl population dynamics under climate change - Does the spatial variation of density dependence and environmental effects matter? *Biological Conservation*, 194, 80–88.

Zedler, J.B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources*, 30(1), 39-74. https://doi.org/10.1146/annurev.energy.30.050504.144248