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Seasonal changes in composition and numbers of bird species on the territory of the Yerevan Botanical Garden

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Abstract - This study was conducted in the Yerevan Botanical Garden from 2022 to 2023. The transect method, widely recognized for its effectiveness in studying bird populations across diverse habitats, was employed to monitor birds in the garden. To assess bird diversity, we utilized two widely accepted diversity indices: the Shannon-Wiener index and the Simpson diversity index.

Over the course of the research, 54 bird species were recorded in the Botanical Garden. These included 16 sedentary species, 13 nesting species, 9 wintering species, and 9 migratory species. Additionally, 7 species were observed sporadically as single (random) occurrences. Notably, we documented an unexpected observation of Eurasian Siskin (*Spinus spinus*) in June, a species traditionally considered a wintering bird according to the available literature.

Seasonal variations in species composition and abundance were evident. The highest species richness was recorded in open habitats during spring, while the lowest was observed in forest habitats during autumn. Similarly, the number of individual birds peaked in open habitats during summer and declined in winter.

The presence of five threatened species, including four listed in the Red Book of the Republic of Armenia and two on the IUCN Red List, underscores the Yerevan Botanical Garden's significance as a sanctuary for bird conservation.

Key words: bird diversity, urban green spaces, threatened species, Armenia.

Riassunto - Cambiamenti stagionali nella composizione e nel numero delle specie di uccelli presenti nel territorio del Giardino Botanico di Yerevan.

Questo studio è stato condotto nel Giardino Botanico di Yerevan dal 2022 al 2023. Per monitorare gli uccelli nel giardino è stato utilizzato il metodo del transetto, ampiamente riconosciuto per la sua efficacia nello studio delle popolazioni di uccelli in habitat diversi. Per valutare la diversità degli uccelli, abbiamo utilizzato due indici di diversità ampiamente accettati: l'indice di Shannon-Wiener e l'indice di diversità di Simpson.

Nel corso della ricerca, nel Giardino Botanico sono state registrate 54 specie di uccelli. Queste includevano 16 specie sedentarie, 13 specie nidificanti, 9 specie svernanti e 9 specie migratorie. Inoltre, 7 specie sono state osservate sporadicamente come presenze singole (casuali). In particolare, abbiamo documentato un'osservazione inaspettata del lucherino eurasiatico (*Spinus spinus*) nel mese di giugno, una specie tradizionalmente considerata un uccello svernante secondo la letteratura disponibile.

Le variazioni stagionali nella composizione e nell'abbondanza delle specie erano evidenti. La maggiore ricchezza di specie è stata registrata negli habitat aperti durante la primavera, mentre la minore è stata osservata negli habitat forestali durante l'autunno. Allo stesso modo, il numero di singoli uccelli ha raggiunto il picco negli habitat aperti durante l'estate e è diminuito in inverno.

La presenza di cinque specie minacciate, di cui quattro elencate nel Libro Rosso della Repubblica di Armenia e due nella Lista Rossa dell'IUCN, sottolinea l'importanza del Giardino Botanico di Yerevan come santuario per la conservazione degli uccelli.

Parole chiave: diversità degli uccelli, spazi verdi urbani, specie minacciate, Armenia.

Introduction

Urban green spaces are crucial for biodiversity conservation in increasingly urbanized landscapes. These areas provide essential habitats for various species, particularly birds, which are often considered to be indicators of ecosystem health (Aronson *et al.*, 2014). Botanical gardens, as specialized urban green spaces, offer unique opportunities for biodiversity conservation because of their diverse plant collections and structured habitats (Paker *et al.*, 2013). The importance of urban green spaces for biodiversity conservation is multifaceted. They serve as refugia for native species, provide connectivity between fragmented habitats, and contribute to the overall ecological function of urban ecosystems (Beninde *et al.* 2015). In the context of avian diversity, urban green spaces offer critical resources such as nesting sites, food sources, shelter from predators, and harsh urban conditions (Goddard *et al.*, 2010).

In particular, botanical gardens possess characteristics that make them valuable for bird conservation. Their diverse plant collections, often including native and exotic species, create complex vegetation structures that support a wide range of bird species with different habitat requirements (Threlfall *et al.*, 2016). Additionally, management practices in botanical gardens, such as limited pesticide use and the presence of water, can enhance their suitability for birds (Cornelis & Hermy, 2004).

Birds play an essential role in ecosystem functioning, including pollination, seed dispersal, and pest control (Whelan *et al.*, 2015). Their presence and diversity in urban green spaces can indicate the overall health of these ecosystems and provide insights into the effectiveness of conservation strategies (Chace & Walsh, 2006). Therefore, studying bird communities in botanical gardens can offer valuable information for urban planners and conservationists seeking to enhance city biodiversity.

Despite the recognized importance of urban green spaces for biodiversity, there remains a need for more comprehensive studies on avian diversity in botanical gardens across different geographic regions and seasons. Such research can contribute to our understanding of how these specialized urban habitats support bird populations and inform management practices to enhance their conservation value.

The purpose of our work was to study the species composition of birds in the Yerevan Botanical Garden, determine their seasonal movements, distribution among the biotopes available in the garden, quantify the species, and compare the data we obtained with those already published. Moreover, such a study, conducted throughout the whole year with constant frequency, has never been conducted in the Yerevan Botanical Garden.

Methods

The research was carried out in the territory of the Botanical Garden of the city of Yerevan. Yerevan city is located in the northeastern part of the Ararat Plain and the central part of the Armenian Highlands, on both banks of the Hrazdan River. The altitude ranges from 865 to 1390 m. The territory of Yerevan includes two landscape zones: up to 1000 m in altitude, there are desert-semi-desert landscapes, and above that, there are dry mountain steppes (Cadastre Committee of the Republic of Armenia, 2008; Sanasaryan & Viñals, 2020).

The Yerevan Botanical Garden, founded in 1935, was designed to preserve rare and endangered Armenian flora. It is located in a mountainous area at an altitude of 1200-1250 meters and covers an area of 80 ha (Kazaryan *et al.* 1985).

The research was conducted from March 13, 2022, to February 26, 2023. Observations were performed twice a month, every second and fourth Sunday in the morning, starting 15 minutes after dawn, with an average duration of 3 hours. There were 24 fieldwork days in total.

We used the transect method to study the birds in the Botanical Garden. The transect method is effective for studying bird populations in various habitats, including urban green spaces and botanical gardens. Three transect lines were defined to cover all three habitat types. We defined a fixed-width strip on either side of the transect line, 0-50 m, 50-100 m, and more than 100 m. We walked quietly to minimize

disturbance at a steady pace (approximately 1-2 km/h). We recorded the species, number of individuals, and their distance from the transect line.

For bird identification, we used NABU binoculars with a magnification power of 10×42. During fieldwork, in addition to the species and number of individuals registered when crossing the route, the registration forms recorded the start and end times of the survey, as well as the weather conditions.

We divided all data into four periods corresponding to spring, summer, autumn, and winter seasons. To determine how vegetation patterns influence bird species composition and distribution, we divided the territory of the Botanical Garden into three conditional sections, along which our survey routes were laid, marked on map #1 in yellow, green, and red, respectively (Fig. 1).

The yellow transect route (length 1 km) contains alleys of Caucasian Lime (*Tilia caucasica*), Small-leaved Lime (*Tilia cordata*), Chestnut-leaved Oak (*Quercus castaneifolia*), English Oak (*Quercus robur*), Osage Orange (*Maclura pomifera*), and Bolle's Poplar (*Populus bolleana*). These tree species are mainly forest-forming and have a height of 20-30 m.

The section of the transect route marked in green (length 1.69 km) is conventionally classified as an open habitat since open spaces and bushes predominate here. However, there are also scattered trees of smaller height compared to the first section, including a grove of Crimean Pine (*Pinus pallasiana*), as well as Chestnut-leaved Oak (*Quercus castaneifolia*), English Oak (*Quercus robur*), Honeysuckle (*Lonicera* spp.), Purging Buckthorn (*Rhamnus cathartica*), European Ash (*Fraxinus excelsior*), Elm (*Ulmus* spp.), Maple (*Acer* spp.), Blackthorn (*Prunus divaricata*), Rose (*Rosa* spp.), Eastern Red Cedar (*Juniperus virginiana*), Hawthorn (*Crataegus* spp.), and Cornelian Cherry (*Cornus australis*).

The transect route marked in red (length 0.95 km) runs through the central urbanistic area of the Botanical Garden, where administrative buildings are located, and ornamental shrubs and herbs grow. This is the most crowded and urbanized area. Among the tree species found here, there were Eastern Cottonwood (*Populus deltoides*), English Oak (*Quercus robur*), Honey Locust (*Gleditsia triacanthos*), Norway Spruce (*Picea abies*), and Green Ash (*Fraxinus pennsylvanica*). Among the shrubs, the following species were recorded: Caucasian Mock Orange (*Philadelphus caucasicus*), Armenian Rowan (*Sorbus hajastana*), Bird Cherry (*Padus avium*), Eastern Red Cedar (*Juniperus virginiana*), Savin Juniper (*Juniperus sabina*), Common Privet (*Ligustrum vulgare*), Large-thorned Hawthorn (*Crataegus macracantha*), and others.

To analyze the bird diversity in the Yerevan Botanical Garden, two commonly used diversity indices were employed: the Shannon-Wiener Index and the Simpson Diversity Index. The Shannon-Wiener Index (H') was calculated to measure species diversity, accounting for both species richness and evenness (Magurran, 2004). The formula used was: $H' = -\sum (p_i * \ln p_i)$, where H' is the Shannon-Wiener Diversity Index, p_i is the proportion of individuals belonging to species i , and $\ln$ is the natural logarithm.

The Simpson Diversity Index (D) was used to measure the probability that two randomly selected individuals from the community belong to different species (Simpson, 1949). The formula used was: $D = 1 / \sum (p_i^2)$, where D is the Simpson Diversity Index, and p_i is the proportion of individuals belonging to species i .

For both indices, data collected from the transect surveys were used. Species abundance and richness were recorded for each of the three defined habitat types (forest habitat, open habitat, and semi-urban habitat) within the Botanical Garden. Calculations were performed using R statistical software (R Core Team, 2021) with the 'vegan' package (Oksanen *et al.*, 2020).

These diversity indices provide complementary information about the bird community structure in the study area, with the Shannon-Wiener Index being more sensitive to rare species and the Simpson Diversity Index giving more weight to common species (Magurran, 2004).

Results

During 1 year of research, we registered 54 species of birds on the territory of the Botanical Garden (Tab. 1). Of the total number of species found in the Botanical Garden, 16 are breeding resident species, 13 are breeding migrant species, nine are wintering, and nine are migrants. Another seven species are presented occasionally, as single (random) observations. The unexpected record was the single registration of Eurasian Siskin (*Spinus spinus*) in June, which is considered to be a wintering species by the available literature.

Five species are of conservation concern: 4 species are included in the Red Book of Animals of the Republic of Armenia, and 2 in the IUCN Red List (Red Book of Animals of the Republic of Armenia, 2010). The Woodchat Shrike (*Lanius senator*) is included in both lists (Tab. 2). Between them, Levant Sparrowhawk (*Tachyspiza brevipes*) is a breeding species in the Yerevan Botanical Garden, while Redwing (*Turdus iliacus*) is a wintering species. The remaining three species: European Roller (*Coracias garrulus*), Woodchat Shrike (*Lanius senator*), and Semicollared Flycatcher (*Ficedula semitorquata*) were found only during spring migration.

Seasonal changes in species composition

The highest number of species was observed in open habitats during springtime (Fig. 2), while the lowest during autumn in the forest habitat. Regarding the number of observed individuals, the highest number was recorded in open habitats in summer, while the lowest number was observed in open habitats during winter (Fig. 3).

Species richness and diversity indices

The Shannon-Wiener Index ranged from 1.76 in the forest habitat during autumn to 2.56 during summer in the open habitat (Fig. 4). The Simpson Diversity Index ranged from 3.86 in the forest habitat during autumn to 9.58 during summer in the open habitat (Fig. 5).

Discussion

Currently, Armenia is home to 377 bird species from 22 orders, with 251 species known to breed within the country (Aghababyan *et al.*, 2024). This figure represents approximately one-third of Europe's bird species. Within the Yerevan city limits, 170 species have been documented (Adamian & Klem, 1999). A study conducted in the Yerevan Botanical Garden identified a diverse avian population, recording 54 species over a year-long period, emphasizing the garden's significance as an urban green space for bird diversity. This finding aligns with other research, such as a study of Tel-Aviv public gardens that observed 65 bird species (Paker *et al.*, 2013), a study in Siena's botanical garden that recorded 51 species (Favilli *et al.*, 2012), and research in San Giuliano Urban Park that documented 80 species (Stival, 2008). In comparison, a 2-year study at Villa Borghese in Rome identified 37 bird species (Fratlicelli, 2005). The variety of plant species in botanical gardens positively influences bird species richness and diversity, as demonstrated by both the Yerevan Botanical Garden study and other research, indicating a relationship between green spaces and species abundance. For instance, research in Bari, Italy, found that Lama Balice Park had an estimated richness of 50.6 species, while the more urbanized Piazza Umberto had only 11.3 species (Ferrara *et al.*, 2008). Additionally, a study in Villa Doria Pamphili, Roma, recorded 23 nesting bird species with high breeding bird density, attributed to the park's environmental heterogeneity, particularly the presence of marginal areas or ecotones (Battisti, 1986). This highlights that urban parks can function as crucial habitats for bird species. However, it also stresses that the diversity, size, and connectivity of these green spaces with extra-urban environments are vital for maintaining bird species richness, as noted in the Bari study (Ferrara *et al.*, 2008).

The Yerevan Botanical Garden study found seasonal variations in species composition and abundance, with the highest number of species recorded in open habitats during spring. This supports the idea that garden management practices and landscape features significantly influence bird communities. The

study's observation of higher diversity in open habitats during summer suggests that these areas may offer a wider range of resources and niches for birds, consistent with findings that diverse and dense shrubberies attract a greater variety of bird species (Paker *et al.*, 2013; Mayorga *et al.*, 2020).

The presence of five species of conservation concern in the Yerevan Botanical Garden underscores its significance for bird conservation. This aligns with the broader role of botanical gardens in supporting biodiversity within urban environments. However, the study also revealed some patterns that differ from natural ecosystems, such as the highest diversity being observed in open habitats rather than forest habitats. This discrepancy may be related to the unique characteristics of botanical gardens, as noted by Pautasso and Parmentier (2007) regarding the positive latitudinal gradient in species richness in botanical gardens compared to natural ecosystems.

The Yerevan study's findings on the importance of diverse habitat types within urban green spaces for supporting a wide range of bird species throughout the year are consistent with recommendations from other research. To enhance bird species richness and abundance, garden designers should prioritize diverse plant species, particularly native trees and shrubs, while limiting large lawns and creating areas inaccessible to dogs and people (Paker *et al.*, 2013; Mayorga *et al.*, 2020).

Future research should focus on the impact of climate change on botanical gardens and their bird populations, as well as the potential for these spaces to contribute to conservation efforts and public engagement in bird diversity studies (Primack *et al.*, 2021; D'Antraccoli *et al.*, 2023). The Yerevan Botanical Garden study provides valuable insights for urban planners and conservationists, emphasizing the need for diverse habitat types within urban green spaces to support avian biodiversity throughout the year.

Conclusions

The study of bird diversity in the Yerevan Botanical Garden over a 1-year period revealed a rich avian community, with 54 species recorded across different seasons and habitat types. The garden's diverse vegetation structure, including forest, open, and semi-urban habitats, supports a variety of bird species with different ecological requirements. The presence of both resident and migratory birds highlights the garden's importance as a year-round habitat and stopover site.

Seasonal variations in species composition and abundance were observed, with the highest number of species recorded in open habitats during spring, while the lowest was found in forest habitats during autumn. The number of individuals peaked in open habitats during summer and was lowest in open habitats during winter. These fluctuations reflect the dynamic nature of urban bird communities and the influence of seasonal factors on bird distribution and behavior.

The presence of five species of conservation concern, including four listed in the Red Book of the Republic of Armenia and two in the IUCN Red List, underscores the botanical garden's significance for bird conservation. The garden provides critical habitat for both breeding and wintering species of conservation importance, as well as serving as a stopover site for migratory species.

Diversity indices (Shannon-Wiener and Simpson) varied across habitats and seasons, indicating differences in species richness and evenness. The highest diversity was observed in open habitats during summer, suggesting that these areas may offer a wider range of resources and niches for birds during this season.

These findings emphasize the importance of the Yerevan Botanical Garden as an urban green space for maintaining bird diversity in the city. The study provides valuable insights for urban planners and conservationists, highlighting the need for diverse habitat types within urban green spaces to support a wide range of bird species throughout the year. Future management strategies should focus on preserving and enhancing the garden's habitat diversity to ensure its continued role in urban biodiversity conservation.

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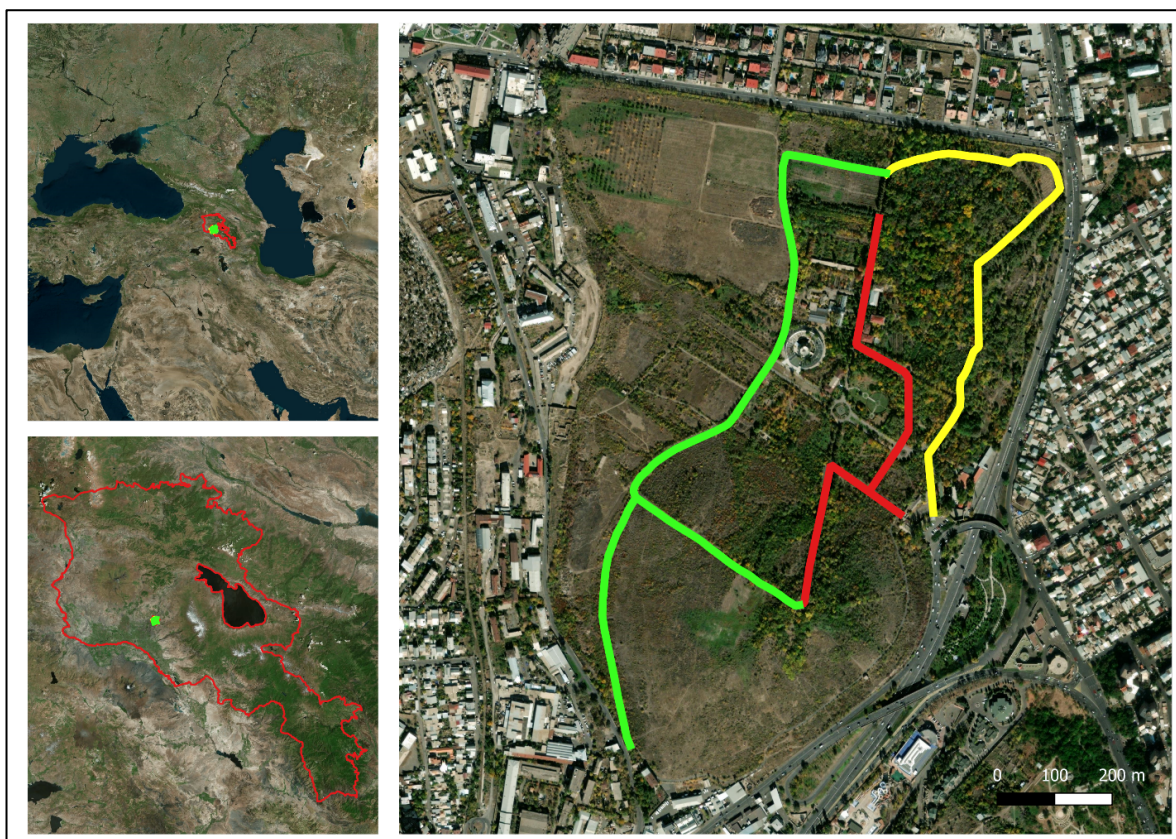


Fig. 1 – Upper left: position of Armenia in the wider area around the Caucasus; down left: Position of the city of Yerevan in the borders of Armenia (green dot); right: Performed transects in different habitats within Yerevan Botanical Garden. / In alto a sinistra: posizione dell'Armenia nell'area più ampia del Caucaso; in basso a sinistra: posizione della città di Yerevan all'interno dei confini dell'Armenia (punto verde); a destra: transetti effettuati in diversi habitat all'interno del Giardino Botanico di Yerevan.

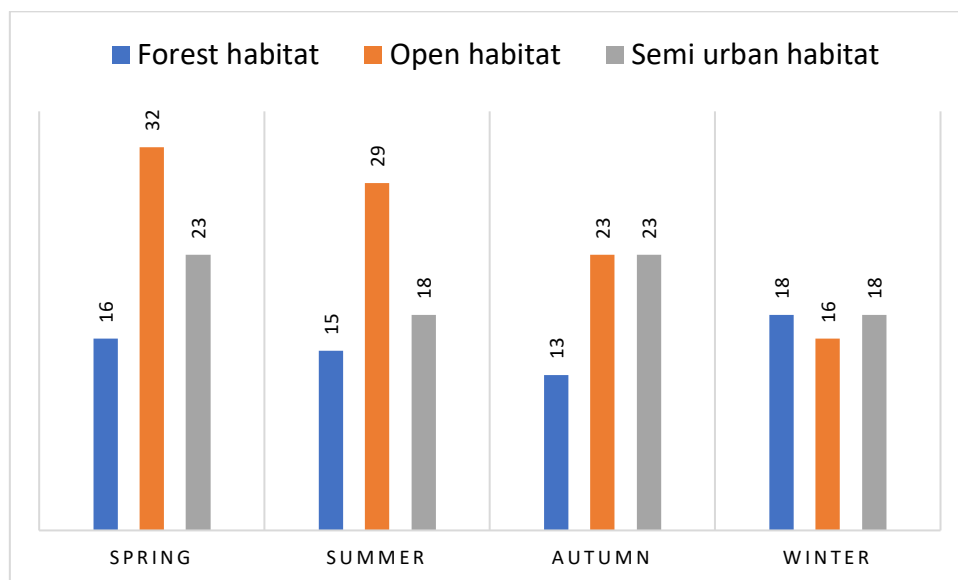


Fig. 2 – Observed species number during different seasons in one of the three present habitats in the Yerevan Botanical Garden. / Numero di specie osservate durante le diverse stagioni in uno dei tre habitat presenti nel Giardino Botanico di Yerevan.

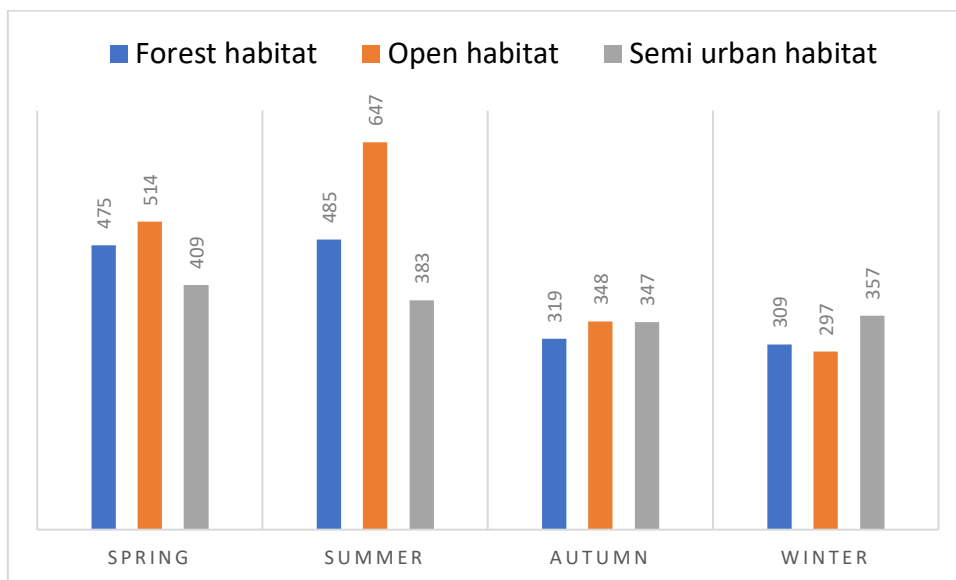


Fig. 3 – Bird abundance during four seasons in the three habitat types in the Yerevan Botanical Garden. / Abbondanza di uccelli durante le quattro stagioni nei tre tipi di habitat del Giardino Botanico di Yerevan.

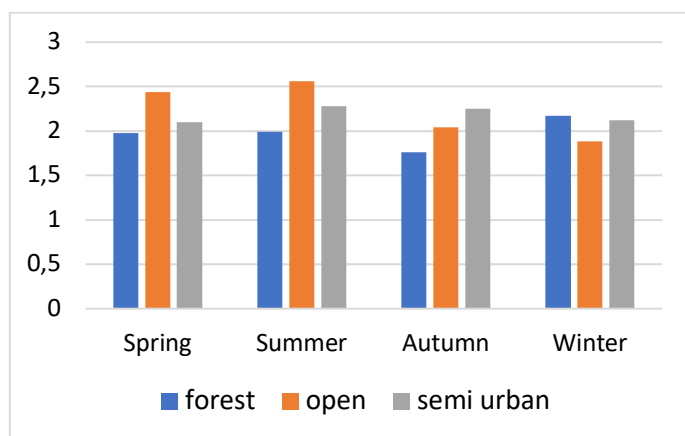


Fig. 4 – The Shannon-Wiener Index values relative to season and habitat type. / Valori dell'indice di Shannon-Wiener relativi alla stagione e al tipo di habitat.

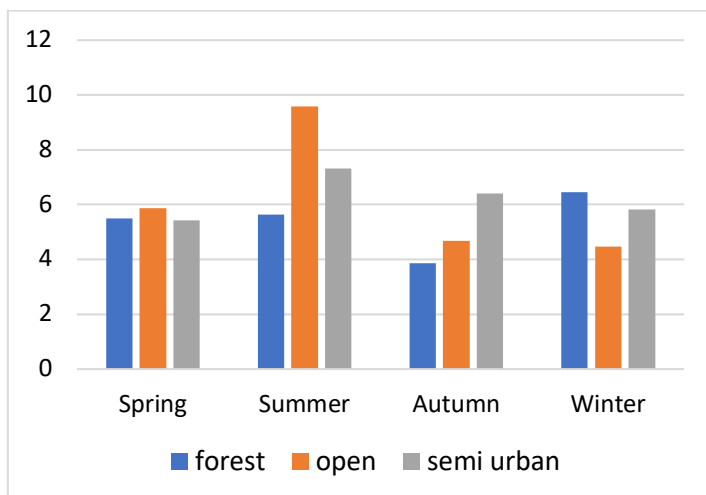


Fig. 5 – The Simpson Diversity Index values relative to season and habitat type. / Valori dell'indice di diversità di Simpson relativi alla stagione e al tipo di habitat.

Tab. 1 – Phenology of recorded species. / Fenologia delle specie registrate.

No.	Latin name	Common name	R	B	W	M	S obs.
1	<i>Accipiter nisus</i>	Eurasian Sparrowhawk	+				
2	<i>Tachyspiza brevipes</i>	Levant Sparrowhawk		+			
3	<i>Buteo buteo</i>	Common Buzzard					+
4	<i>Falco tinnunculus</i>	Common Kestrel	+				
5	<i>Columba palumbus</i>	Common Wood Pigeon	+				
6	<i>Streptopelia decaocto</i>	Eurasian Collared Dove					+
7	<i>Spilopelia senegalensis</i>	Laughing Dove					+
8	<i>Cuculus canorus</i>	Common Cuckoo		+			
9	<i>Asio otus</i>	Long-eared Owl					+
10	<i>Caprimulgus europaeus</i>	European Nightjar				+	
11	<i>Merops apiaster</i>	European Bee-eater		+			
12	<i>Coracias garrulus</i>	European Roller				+	
13	<i>Upupa epops</i>	Eurasian Hoopoe		+			
14	<i>Picus viridis</i>	European Green Woodpecker					+
15	<i>Dendrocoptes medius</i>	Middle Spotted Woodpecker					+
16	<i>Dendrocopos syriacus</i>	Syrian Woodpecker	+				
17	<i>Hirundo rustica</i>	Barn Swallow		+			
18	<i>Prunella modularis</i>	Dunnock			+		
19	<i>Turdus merula</i>	Common Blackbird	+				
20	<i>Turdus iliacus</i>	Redwing			+		
21	<i>Turdus viscivorus</i>	Mistle Thrush			+		
22	<i>Turdus pilaris</i>	Fieldfare			+		
23	<i>Erithacus rubecula</i>	European Robin			+		
24	<i>Luscinia megarhynchos</i>	Common Nightingale		+			
25	<i>Muscicapa striata</i>	Spotted Flycatcher		+			
26	<i>Ficedula semitorquata</i>	Semicollared Flycatcher				+	
27	<i>Phoenicurus ochruros</i>	Black Redstart		+			
28	<i>Phoenicurus phoenicurus</i>	Common Redstart		+			

29	<i>Saxicola rubicola</i>	European Stonechat				+	
30	<i>Oenanthe oenanthe</i>	Northern Wheatear				+	
31	<i>Sylvia atricapilla</i>	Eurasian Blackcap				+	
32	<i>Curruca curruca</i>	Lesser Whitethroat		+			
33	<i>Aegithalos caudatus</i>	Long-tailed Tit	+				
34	<i>Cyanistes caeruleus</i>	Eurasian Blue Tit	+				
35	<i>Parus major</i>	Great Tit	+				
36	<i>Oriolus oriolus</i>	Eurasian Golden Oriole				+	
37	<i>Lanius collurio</i>	Red-backed Shrike		+			
38	<i>Lanius minor</i>	Lesser Grey Shrike				+	
39	<i>Lanius senator</i>	Woodchat Shrike				+	
40	<i>Garrulus glandarius</i>	Eurasian Jay	+				
41	<i>Pica pica</i>	Eurasian Magpie	+				
42	<i>Coloeus monedula</i>	Western Jackdaw	+				
43	<i>Corvus cornix</i>	Hooded Crow	+				
44	<i>Sturnus roseus</i>	Rosy Starling		+			
45	<i>Passer domesticus</i>	House Sparrow	+				
46	<i>Passer montanus</i>	Eurasian Tree Sparrow	+				
47	<i>Fringilla coelebs</i>	Common Chaffinch			+		
48	<i>Fringilla montifringilla</i>	Brambling			+		
49	<i>Chloris chloris</i>	European Greenfinch	+				
50	<i>Carduelis carduelis</i>	European Goldfinch	+				
51	<i>Spinus spinus</i>	Eurasian Siskin					+
52	<i>Carpodacus erythrinus</i>	Common Rosefinch		+			
53	<i>Coccothraustes coccothraustes</i>	Hawfinch			+		
54	<i>Emberiza citrinella</i>	Yellowhammer			+		

R, breeding resident; B, breeding migrants; W, wintering migrants; M, passage migrants; S obs, single, random observations.

Tab. 2 – Recorded species in Yerevan Botanical Garden of conservation concern. / Specie registrate nel Giardino Botanico di Yerevan di interesse conservazionistico.

No	Species	Red Book of Animals of the Republic of Armenia	IUCN Red List
1	Levant Sparrowhawk	+	
2	European Roller	+	
3	Woodchat Shrike	+	Near Threatened
4	Semicollared Flycatcher	+	
5	Redwing		Near Threatened