VARIATION IN AVIAN DIVERSITY IN RELATION TO PLANT SPECIES IN URBAN PARKS OF AYDIN, TURKEY

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Abstract. Among wildlife species, birds are important indicators of biodiversity and habitat quality in urban ecosystems. Parks, which are among the important components of urban ecosystems, are home to many bird species with their diversity of plant species. Due to this aspect, parks make significant contributions to increase bird diversity. The bird species were observed with the naked eye and using an Olympus 10x50 DPS I brand binocular. Bird observations were performed on sunny days without rain and excessive wind in the mornings (07.00-09.00 a.m./2 h after sunrise) and evenings. Sixteen bird species observed in urban parks of Aydin comprised 11 native, 11 resident and 9 insectivorous species. The Eurasian Collared-Dove (*Streptopelia decaocto* Frivaldszky), Eurasian Jackdaw (*Corvus monedula* L.), Hooded Crow (*Corvus cornix* L.), Great Tit (*Parus major* L.), and House Sparrow (*Passer domesticus* L.) were the most frequently observed bird species in all parks. The Australian Pine (*Casuarina equisetifolia* L.) attracted the highest number of bird species with 12 species, followed by the Turkish Pine (*Pinus brutia* Ten.) with 11 species. A significant variance was found between plant species and avian diversity.
Keywords: *biodiversity, bird richness, habitat, landscape ecology, species distribution*

Introduction

Many cities in the world are home to many wildlife species since they have unlimited opportunities that meet vital needs such as food, water, shelter, and nesting (Pacheco and Vasconcelos, 2007; Baldock et al., 2015; Goertzen and Suhling, 2015; Kowarik and von der Lippe, 2018). Among these wildlife species, birds take an important place since they are common and easily observable (Suarez-Rubio et al., 2016; Bradbury, 2019; Moss and Martin, 2019) Cities are considered to be ecosystems with the potential to support various bird communities (Shochat et al., 2010). Of all bird species in the world, 20% live in cities (Aronson et al., 2014). Urban bird communities are divided into five groups based on their relationships with the urban ecosystem: urban avoiders, urban exploiters, urban adapters, residents, and migrants (Blair, 1996).

Parks have a high diversity of vegetation since they are usually the most heterogeneous green areas in the urban ecosystem (Gilbert, 1989; Hadidian et al., 1997; Rottenborn, 1999).

Because of the high diversity of vegetation, parks are among the important habitats for birds in cities (Jokimäki, 1999). Parks make significant contributions to the conservation of bird diversity and richness (Cornelis and Hermy, 2004; Khera et al., 2009; Carvajal-Castro et al., 2019).

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Birds are important indicators of habitat quality (Fontana et al., 2011a). The bird life in parks also increases the life quality of users. Park visitors are in search of a wildlife atmosphere, which differs from their work environments (Baines, 2000). Urban birds and their diversity make up a significant factor regarding how people can experience urban nature. Since communicating with birds means communicating with nature, it improves the physical, mental, and emotional health of urban dwellers (Moss and Martin, 2019).

All birds have different habitat requirements. However, they need food which they can feed on and feed their offspring with, and trees as well as shrubs where they can shelter and build a nest (Bradbury, 2019).

Bird communities in cities largely vary depending on the type and structure of vegetation (Sewell and Catterall, 1998; Fernández-Juricic and Jokimäki, 2001; White et al., 2005; Villegas and Garitano-Zavala, 2010). It was found that vegetation was positively associated with bird species richness. The more species of trees and shrubs there are that produce seeds and fruits and bloom at different times, the more bird species parks attract (Bauer, 2012; Bradbury, 2019). Trees are considered to be one of the most important plant components that increase bird species richness and diversity in parks since they provide opportunities for nutrition, shelter, and nesting (Fontana et al., 2011b; Aronson et al., 2014; Beninde et al., 2015). The shrub vegetation in parks is considered an important microhabitat since it decreases the problems to be caused by people by reducing their visibility, gives birds a chance to escape, and reduces the risk of hunting (Martín and López, 1995; Kramer and Bonenfant, 1997; Yang et al., 2015).

The most important problem related to wildlife in parks is that most plant species are exotic (Taylor, 2015). Most of the exotic species are less important for native bird species since they have a low food supply. Most of the plants in wildlife-friendly parks comprise native species (Bradbury, 2019).

The most important way for parks to increase the value of bird habitat is that plants are in layers in the form of trees, shrubs, and groundcovers as in nature (Bauer, 2012). This diversity of vegetation layers increases nutritional, sheltering, and nesting opportunities for different bird species (Marzluff and Ewing, 2001; Tews et al., 2004).

Information on the patterns of urban bird populations and communities appeared in the 1970s (Emlen, 1974). Most of the studies on urban birds addressed the key issues of abundance and distribution (Shochat et al., 2010). A lot of studies were conducted on birds within the context of urban ecology (Lepczyk and Warren, 2012; Shwartz et al., 2013; Gil and Brumm, 2014). In very few studies, the importance of vegetation structure for bird communities was examined (Keller et al., 2003; Macgregor-Fors and Schondube, 2011). However, variations in the distribution of bird species in cities depending on the vegetation profile remains unclear. There are no studies examining the relationship between bird diversity and plant species in the parks in Turkey, despite its potential significance. The study hypothesis is that in urban parks of Aydin, depending on the vegetation profile, the diversity of birds would change.

In the study, 1-the vegetation structure in the parks, which made up the study area, was revealed and 2- to what extent this vegetation affected the variation in bird species was investigated.

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Materials and Methods

Study area

The study area was the Pinarbasi Recreation Area, Aytepe Recreation Area, Nevzat BICER Park, and Ismet SEZGIN Park in Aydın city (*Figure 1*). While the population of Aydin city in 2019 was 293,816 (TUIK, 2020), its altitude is 59 m, and its surface area is 631 km^2. The Mediterranean climate prevails in the city. The mean annual temperature is 17.8 °C, and the mean annual amount of precipitation is 646 mm. The Pinarbasi Recreation Area is 32,195.63 m^2, the Aytepe Recreation Area is 15,828.97 m^2, Nevzat BICER Park is 14,663.16 m^2, and Ismet SEZGIN Park is 8,043.85 m^2. The Pinarbasi Recreation Area and Aytepe Recreation Area are on the urban fringe, and Nevzat BICER Park and Ismet SEZGIN Park are in the city center.

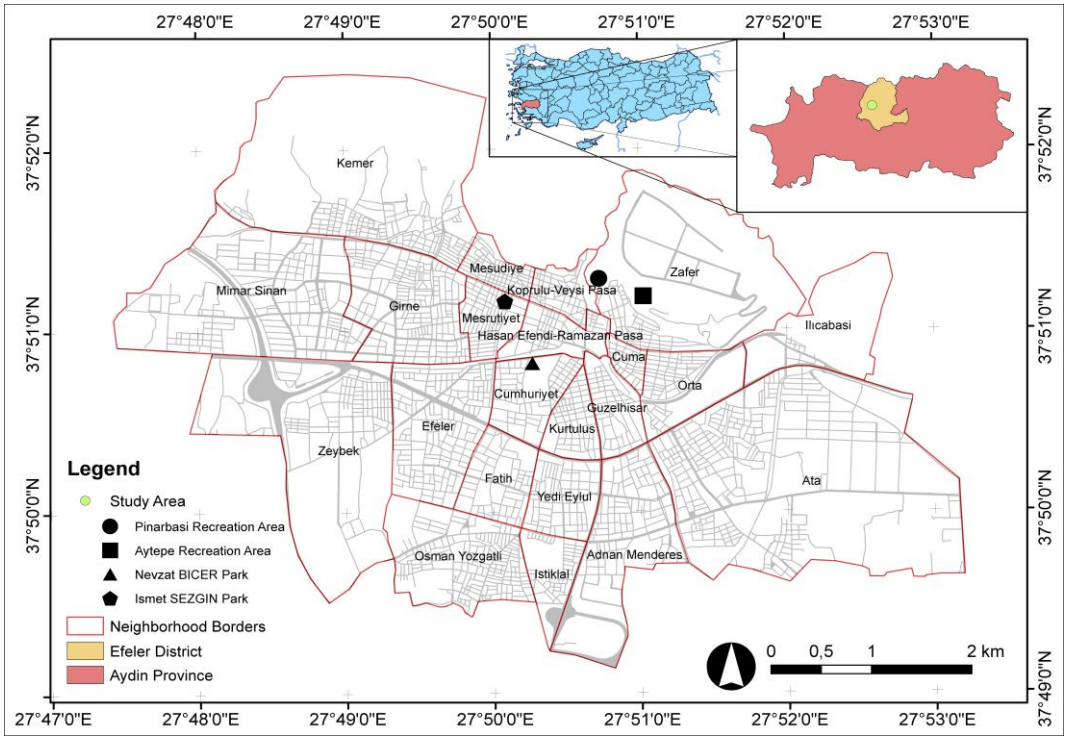

Figure 1. *Study area*

Observation tools

The bird species were observed with the naked eye and using an Olympus 10x50 DPS I brand binocular.

Bird data collection

Bird observations were performed on sunny days without rain and excessive wind, in the mornings (07.00-09.00 a.m./2 h after sunrise) and evenings (17.00-19.00 p.m./ 2 h before dark) (Meles and Bogale, 2018) during which bird activity was maximum, in the non-breeding season of 2019 between 16-26 September (Threlfall et al., 2016; Kale et al., 2018; Carvajal-Castro et al., 2019; Mao et al., 2019; Vaccaro et al., 2019). The non-breeding season is defined as the period during which wintering birds are likely to be

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present and the resident bird species are unlikely to breed (Braden et al., 2007). Bird data were collected by using a standard five-minute point-count method (Heezik et al., 2010; Yang et al., 2015; van Camacho-Cervantes et al., 2018; Wolff et al., 2018; Filloy et al., 2019; Vaccaro et al., 2019). All birds heard or seen (McCurdy, 2016; Threlfall et al., 2016; Callaghan et al., 2018; Filloy et al., 2019; Vaccaro et al., 2019) within a radius of 25 m from each observation point (Shanahan et al., 2011; Yang et al., 2015) were observed. The observations were performed by walking on the line between observation points (Chong et al., 2014; Yang et al., 2015; Kale et al., 2018). The observations were performed at 67 points, including 33 points in the Pinarbasi Recreation Area, 19 points in the Aytepe Recreation Area, 9 points in Nevzat BICER Park, and 6 points in Ismet SEZGIN Park (*Figure 2*). In four parks which made up the study area, 32 hours of observations were performed in 16 different time periods in 8 days. The observations were performed by two observers trained on visual and auditory bird identification (Verner and Milne, 1989).

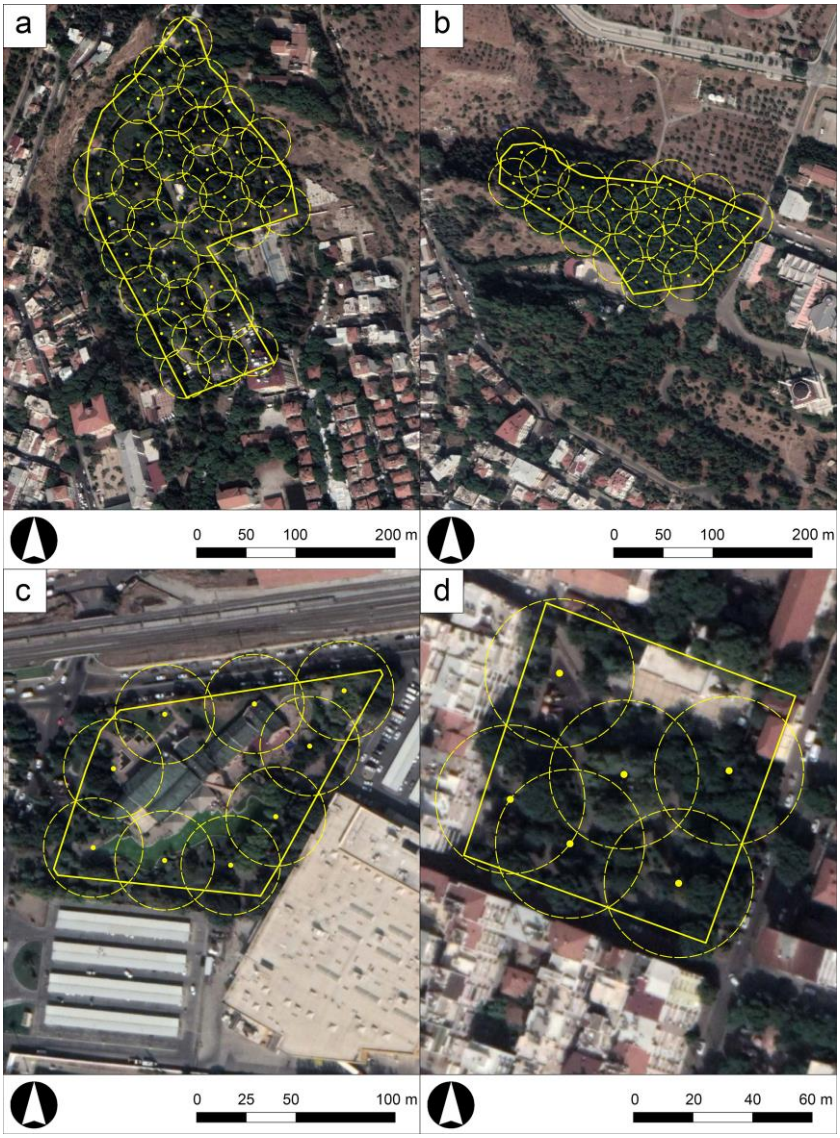

Figure 2. *Observation points (a) Pinarbasi Recreation Area, (b) Aytepe Recreation Area, (c) Nevzat BICER Park, (d) Ismet SEZGIN Park*

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Data analysis

The feature data used in bird identification were collected from published sources (Heinzel et al., 1995) and online bird databases (Bird Life International, 2011; eBird, 2012; Rodewald, 2015; The Cornell Lab, 2017). The published sources (Karamanoglu, 1976; Mamıkoglu, 2010; Akkemik, 2018) were used in the identification of plants. The observation points were created on a Quickbird satellite image using ArcMap 10.7 software. The birds were classified according to their scientific names and taxonomic structure (Kirwan et al., 2008; AOU, 2009; Gill and Donsker, 2020; TRAKUS, 2020), native and exotic status, residency status, urban associations (Howell and Webb, 1995), and guilds.

Statistical analysis

The statistical software package SPSS 25.0 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used to analyze statistically the study data. First, the data's normality assumption was tested. It was determined that the data not met the normality assumption. Therefore, it was applied non-parametric tests to the data. Using the Mann-Whitney U test, the connection between binary independent categorical variables was analyzed and the connection between triple independent categorical variables was analyzed using the Kruskal Wallis H test. Statistical analysis included only plants on which birds were observed and the birds on which they were observed, not all plant species and bird species. Plant heights for statistical analysis were classified as short, medium, high for <10 m, 10-20 m and >20 m, respectively. No individual measurements have been taken because all the plant species in the study area are adults. The average plant height was calculated, taking advantage of published sources used in data analysis section.

Results

Plant species and bird species in the study area

While the highest number of native tree species (15 species) was present in the Pinarbasi Recreation Area, the lowest number of native tree species (7 species) was present in the Aytepe Recreation Area and Nevzat BICER Park. While the highest number of exotic tree species (24 species) was present in Nevzat BICER Park, the lowest number of exotic tree species (1 species) was present in the Aytepe Recreation Area. The highest number of native shrub species (6 species) was present in the Pinarbasi Recreation Area and Nevzat BICER Park. However, the lowest number of native shrub species (2 species) was present in the Aytepe Recreation Area. The highest number of exotic shrub species (21 species) was present in Ismet SEZGIN Park, and the lowest number of exotic shrub species (4 species) was present in the Aytepe Recreation Area (*Table 1*).

In the observations performed in four parks in Aydin city, 16 bird species from 9 families were observed. While the highest number of bird species (14 species) was observed in the Pinarbasi Recreation Area, the lowest number of bird species (8 species) was observed in Nevzat BICER and Ismet SEZGİN Parks. The observed birds comprised 11 native, 5 exotic, 11 resident, 5 migrant, 14 urban adapter (5 exotic, 9 native) and 2 urban exploiter (native species) species. While 9 of the observed bird

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species were insectivorous species, 6 and 1 of them were omnivorous and granivorous species, respectively (*Table 2*).

Table 1. *Native and exotic plant species in the study area*

Plant Species	Species and Frequency	Native (N) or Exotic (E)	Urban Parks			
			Pinarbasi Recreation Area	Aytepe Recreation Area	Nevzat BICER Park	Ismet SEZGIN Park
Tree	Species	N	15	7	7	11
		E	21	1	24	13
	Frequency	N	246	616	40	92
		E	269	3	199	51
Shrub	Species	N	6	2	6	4
		E	11	4	15	21
	Frequency	N	452	61	32	64
		E	202	1078	385	724

Table 2. *Bird species observed in the study area*

Latin Name	Common Name	Family	Status*	Urban Parks**			
				PRA	ARA	NBP	ISP
Streptopelia decaocto Frivaldszky	Eurasian Collared-Dove	*Columbidae*	N-R-UA-G	●	●	●	●
Corvus monedula L.	Eurasian Jackdaw	*Corvidae*	N-R-UA-O	●	●	●	●
Corvus cornix L.	Hooded Crow	*Corvidae*	N-R-UE-O	●	●	●	●
Garrulus glandarius L.	Eurasian Jay	*Corvidae*	N-R-UA-O	●	●		
Pica pica L.	Eurasian Magpie	*Corvidae*	N-R-UA-O	●	●		●
Fringilla coelebs L.	Common Chaffinch	*Fringillidae*	N-R-UA-O	●	●		
Motacilla alba L.	White Wagtail	*Motacillidae*	E-M-UA-I	●		●	
Motacilla cinerea Tunstall	Grey Wagtail	*Motacillidae*	E-M-UA-I			●	
Motacilla flava L.	Western Yellow Wagtail	*Motacillidae*	E-M-UA-I	●			
Ficedula parva Bechstein	Red-breasted Flycatcher	*Muscicapidae*	E-M-UA-I		●		●
Muscicapa striata Pallas	Spotted Flycatcher	*Muscicapidae*	E-M-UA-I	●	●	●	
Cyanistes caeruleus L.	Eurasian Blue Tit	*Paridae*	N-R-UA-I	●	●		
Parus major L.	Great Tit	*Paridae*	N-R-UA-I	●	●	●	●
Passer domesticus L.	House Sparrow	*Passeridae*	N-R-UE-O	●	●	●	●
Dendrocopos syriacus (Hemprich & Ehrenberg)	Syrian Woodpecker	*Picidae*	N-R-UA-I	●	●		●
Sitta europaea L.	Eurasian Nuthatch	*Sittidae*	N-R-UA-I	●			
Number of Bird Species Observed:				**14**	**12**	**8**	**8**

Note: *Status: Native or Exotic: N (Native), E (Exotic); Residency Status: R (Resident), M (Migrant); Urban Association: UA (Urban Adapter), UE (Urban Exploiter); Guild: G (Granivore), I (Insectivorous), O (Omnivorous); **Urban Parks: PRA (Pınarbasi Recreation Area), ARA (Aytepe Recreation Area), NBP (Nevzat BICER Park), ISP (Ismet SEZGIN Park)

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The Eurasian Collared-Dove (*Streptopelia decaocto* Frivaldszky), Eurasian Jackdaw (*Corvus monedula* L.), Hooded Crow (*Corvus cornix* L.), Great Tit (*Parus major* L.), and House Sparrow (*Passer domesticus* L.) that were observed in all parks were also the most frequently observed bird species in the parks. In the morning observations, the most frequently observed bird species were the Eurasian Jackdaw in the Pinarbasi Recreation Area, the Eurasian Jay (*Garrulus glandarius* L.) and Great Tit in the Aytepe Recreation Area, and the House Sparrow in Nevzat BICER and Ismet SEZGIN parks. In the evening observations, the most frequently observed bird species were the Eurasian Jackdaw and Eurasian Blue Tit (*Cyanistes caeruleus* L.) in the Pinarbasi Recreation Area, the Great Tit in the Aytepe Recreation Area, the House Sparrow in Nevzat BICER park, and the Eurasian Collared-Dove in Ismet SEZGIN Park (*Table 2*).

Variation in bird species in relation to plant species in the study area

In the Pinarbasi Recreation Area, the highest number of bird species was observed in the Australian Pine (*Casuarina equisetifolia* L.) (12 species), Turkish Pine (*Pinus brutia* Ten.) (9 species), and Oriental Plane Tree (*Platanus orientalis* L.) (8 species). The lowest number of bird species (1 species) was observed in the Japanese Spindle Tree (*Euonymus japonicus* Thunb.), Common Privet (*Ligustrum vulgare* L.), Oriental Sweetgum (*Liquidambar orientalis* Mill.), Japanese Pittosporum [*Pittosporum tobira* (Thunb.) W. T. Aiton], and Black Locust (*Robinia pseudoacacia* L.). The highest number of bird species observed in the Australian Pine were the Hooded Crow, Eurasian Jay, Eurasian Blue Tit, and Eurasian Nuthatch (*Sitta europaea* L.) (*Table 3*).

In the Pinarbasi Recreation Area, among the most frequently observed species in the parks examined, the great tit was observed in 12 tree species and 2 shrub species, the House Sparrow was observed in 10 tree species and 2 shrub species, the Eurasian Jackdaw was observed in 7 tree species, the Hooded Crow was observed in 5 tree species, the Eurasian Collared-Dove was observed in 3 tree species (*Table 3*). While the Western Yellow Wagtail (*Motacilla flava* L.), one species observed only in the Pinarbasi Recreation Area, was not observed in any tree, it was observed only on the ground.

In the Australian Pine, Turkish Pine, and Oriental Plane Tree that attracted the highest number of bird species in the Pinarbasi Recreation Area, most of the bird species were mostly observed in the morning observations. Other tree species on which birds were mostly observed in the morning observations were the Boxelder (*Acer negundo* L.), Italian Cypress [*Cupressus sempervirens* 'Horizontalis' (Mill.) Loudon], Stone Pine (*Pinus pinea* L.), Atlas Cedar [*Cedrus atlantica* (Endl.) Lindl.], and White Mulberry (*Morus alba* L.). In the Australian Pine and Turkish Pine, most of the bird species were also observed in the evening observations. Other species on which the bird species were mostly observed in the evening observations were the Boxelder, White Mulberry, Stone Pine, and Oriental Plane Tree (*Table 3*).

In the Aytepe Recreation Area, the highest number of bird species (11 species) and the lowest number of bird species (2 species) were observed in the Turkish Pine and Olive (*Olea europaea* L.), respectively. The Eurasian Collared-Dove, Eurasian Blue Tit, and Great Tit were most frequently observed in the Turkish Pine (*Table 4*).

In the Aytepe Recreation Area, among the most frequently observed species in the parks examined, the Eurasian Collared-Dove, Great Tit, and House Sparrow were most frequently observed in the Turkish Pine, and the Eurasian Jackdaw and Hooded Crow

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were most frequently observed in the Italian Cypress (Horizontal form) and Turkish Pine (*Table 4*).

Table 3. *Plants on which birds were observed in the Pinarbasi Recreation Area and their time of observation*

Plant Species		**Bird Species***											
Latin Name	**Common Name**	***Sd***	***Cm***	***Cc***	***Gg***	***Pp***	***Fc***	***Ms***	***Cy***	***Pm***	***Pd***	***Ds***	***Se***
Acer negundo L.	Boxelder		M			M	M		ME	M2E	M		
Ailanthus altissima (Mill.) Swingle	Tree of Heaven							E	M	2M			
Casuarina equisetifolia L.	Australian Pine	M	2ME	2M2E	2M2E	2ME	M	E	2M2E	ME	ME	E	2M2E
Catalpa bignonioides Walt.	Southern Catalpa									M	M	M	
Cedrus atlantica (Endl.) Lindl.	Atlas Cedar		M	M	M					M			
Cedrus libani A.Rich.	Cedar of Lebanon			M				ME			M		
Cupressus sempervirens 'Horizontalis' (Mill.) Loudon	Italian Cypress		M		M	ME		E		2M	M		
Eucalyptus camaldulensis Dehnh.	River Red Gum								M	M2E	M		
Euonymus japonicus Thunb.	Japanese Spindle Tree									M			
Ligustrum ovalifolium Hassk.	California Privet					E					2M		
Ligustrum vulgare L.	Common Privet									M			
Liquidambar orientalis Mill.	Oriental Sweetgum										M		
Magnolia grandiflora L.	Southern Magnolia					M					2M		
Morus alba L.	White Mulberry				2ME		M			M2E			
Paulownia tomentosa (Thunb.) Sieb. & Zucc. ex Steud.	Princess Tree		M			M							
Pinus brutia Ten.	Turkish Pine	2M2E	2ME	M2E	2ME			E	M2E	M2E	M		E
Pinus pinea L.	Stone Pine				M			2E	M	2M	M		E
Pittosporum tobira (Thunb.) W.T.Aiton	Japanese Pittosporum										2M		
Platanus orientalis L.	Oriental Plane Tree	ME	2M	2M	2M	2M			M	2ME		E	
Populus nigra L.	Black Poplar				M	M			E				
Robinia pseudoacacia L.	Black Locust									M			

Note: Observation Time: M (Morning), E (Evening); *Bird Species: *Sd* (*Streptopelia decaocto* Frivaldszky), *Cm* (*Corvus monedula* L.), *Cc* (*Corvus cornix* L.), *Gg* (*Garrulus glandarius* L.), *Pp* (*Pica pica* L.), *Fc* (*Fringilla coelebs* L.), *Ms* (*Muscicapa striata* Pallas), *Cy* (*Cyanistes caeruleus* L.), *Pm* (*Parus major* L.), *Pd* (*Passer domesticus* L.), *Ds* (*Dendrocopos syriacus* (Hemprich & Ehrenberg)), *Se* (*Sitta europaea* L.)

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Table 4. *Plants on which birds were observed in the Aytepe Recreation Area and their time of observation*

Plant Species		**Bird Species***										
Latin Name	**Common Name**	***Sd***	***Cm***	***Cc***	***Gg***	***Pp***	***Fc***	***Ms***	***Cy***	***Pm***	***Pd***	***Ds***
Cupressus sempervirens 'Horizontalis' (Mill.) Loudon	Italian Cypress	M	M E	M 2E		2M			M	2M		
Olea europaea L.	Olive									2M	M	
Pinus brutia Ten.	Turkish Pine	2M 2E	2M	2M E	2M E	2M	2M E	2M E	2M 2E	2M 2E	2M E	M

Note: Observation Time: M (Morning), E (Evening); *Bird Species: *Sd* (*Streptopelia decaocto* Frivaldszky), *Cm* (*Corvus monedula* L.), *Cc* (*Corvus cornix* L.), *Gg* (*Garrulus glandarius* L.), *Pp* (*Pica pica* L.), *Fc* (*Fringilla coelebs* L.), *Ms* (*Muscicapa striata* Pallas), *Cy* (*Cyanistes caeruleus* L.), *Pm* (*Parus major* L.), *Pd* (*Passer domesticus* L.), *Ds* (*Dendrocopos syriacus* (Hemprich & Ehrenberg))

In the Aytepe Recreation Area, in the Turkish Pine that attracted the highest number of bird species, all bird species were observed in the morning observations. Another tree species on which birds were mostly observed in the morning observations was the Italian Cypress (Horizontal form). Most of the bird species in the Turkish Pine were also observed in the evening observations. Another species on which bird species were mostly observed in the evening observations was the Italian Cypress (Horizontal form) (*Table 4*).

In Nevzat BICER park, the highest number of bird species was observed in the Silky Oak (*Grevillea robusta* A. Cunn. ex R. Br.) (4 species). The lowest number of bird species was observed in (1 species each) 9 tree species, including the Tree of Heaven [*Ailanthus altissima* (Mill.) Swingle] and Silk Tree (*Albizia julibrissin* Durazz.), and in 2 shrub species comprising the California Privet (*Ligustrum ovalifolium* Hassk.) and Four-Stamen Tamarisk (*Tamarix tetrandra* Pall. ex M. Bieb.) (*Table 5*).

In Nevzat BICER park, among the most frequently observed species in the parks examined, the House Sparrow was observed in 15 tree species and 2 shrub species, the Eurasian Collared-Dove and Eurasian Jackdaw were observed in 9 tree species, and the Hooded Crow and Great Tit were observed in 1 tree species (*Table 5*). The Grey Wagtail (*Motacilla cinerea* Tunstall), which was observed only in Nevzat BICER park, was not observed in any tree; it was observed only on the ground.

In the Silky Oak that attracted the highest number of bird species in Nevzat BICER park, most of the bird species were observed in the morning observations. Other tree species on which the birds were mostly observed in the morning observations were the Boxelder, White Mulberry, and Japanese Pagoda Tree (*Sophora japonica* L.). The species on which bird species were mostly observed in the evening observations were the Boxelder and Russian Olive (*Elaeagnus angustifolia* L.). Other species on which bird species were mostly observed in the evening observations were the White Mulberry and Weeping Willow (*Salix babylonica* L.) (*Table 5*).

In Ismet SEZGIN park, while the highest number of bird species (6 species) was observed in the Australian Pine, the lowest number of bird species (1 species) was observed in the California Privet, Common Privet, White Mulberry, and Turkish Pine. The Eurasian Jackdaw was most frequently observed in the Australian Pine (*Table 6*).

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Table 5. *Plants on which the birds were observed in Nevzat BICER Park and their time of observation*

Plant Species		Bird Species*					
Latin Name	**Common Name**	***Sd***	***Cm***	***Cc***	***Ms***	***Pm***	***Pd***
Acer negundo L.	Boxelder	M	2M 2E				2M 2E
Acer saccharinum L.	Silver Maple	E	M				2E
Ailanthus altissima (Mill.) Swingle	Tree of Heaven						M
Albizia julibrissin Durazz.	Silk Tree						M
Carpinus betulus L.	Common Hornbeam						2M
Cedrus atlantica (Endl.) Lindl. & Gordon	Atlas Cedar		M				
Cupressocyparis leylandii A.B.Jacks. & Dallim	Leyland Cypress	E					ME
Elaeagnus angustifolia L.	Russian Olive	M E	2E		E		
Grevillea robusta A.Cunn. ex R.Br.	Silky Oak	M	M	M			E
Jacaranda mimosifolia D. Don.	Jacaranda	M E			M		M E
Ligustrum ovalifolium Hassk.	California Privet						M E
Magnolia grandiflora L.	Southern Magnolia						M
Morus alba L.	White Mulberry	2M E	M				M 2E
Platanus occidentalis L.	American Sycamore					E	
Prunus cerasifera 'Atropurpurea'	Purple-Leaf Cherry Plum				M E		M
Prunus domestica L	Plum				M		
Prunus persica (L.) Batsch	Peach	M	M				
Robinia pseudoacacia L.	Black Locust				E		2M
Salix babylonica L.	Weeping Willow				ME		2E
Sophora japonica L.	Japanese Pagoda Tree	2M	M				M
Tamarix tetrandra Pall. ex M.Bieb.	Four-Stamen Tamarisk						M
Tilia cordata Mill.	Small-Leaved Lim						2M
Washingtonia robusta H. Wendl.	Mexican Fan Palm		M				

Note: Observation Time: M (Morning), E (Evening); *Bird Species: *Sd* (*Streptopelia decaocto* Frivaldszky), *Cm* (*Corvus monedula* L.), *Cc* (*Corvus cornix* L.), *Ms* (*Muscicapa striata* Pallas), *Pm* (*Parus major* L.), *Pd* (*Passer domesticus* L.)

In Ismet SEZGIN Park, among the most frequently observed species in the parks examined, the House Sparrow was observed in 8 tree species and 2 shrub species, the Eurasian Collared-Dove and Eurasian Jackdaw were observed in 8 tree species, and the Hooded Crow and Great Tit were observed in 2 tree species (*Table 6*).

In the Australian Pine that attracted the highest number of bird species in Ismet SEZGIN Park, most of the bird species were observed in the morning observations. Other tree species on which the birds were mostly observed in the morning observations were the Italian Cypress [*Cupressus sempervirens* 'Pyramidalis' (O. Targ. Tozz.) Nyman], Stone Pine, Kurrajong (*Brachychiton populneus* Schott.), Oriental Plane Tree, and Small-Leaved Lime (*Tilia cordata* Mill.). The species on which bird species were mostly observed in the evening observations were the Stone Pine and Italian Cypress (Pyramidal form). Another species on which bird species were mostly observed in the evening observations was the Oriental Plane Tree (*Table 6*).

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Table 6. *Plants on which the birds were observed in Ismet SEZGIN Park and their time of observation*

Plant Species		**Bird Species***							
Latin Name	**Common Name**	***Sd***	***Cm***	***Cc***	***Pp***	***Fp***	***Pm***	***Pd***	***Ds***
Brachychiton populneus Schott.	Kurrajong	M	2M				M	M	
Casuarina equisetifolia L.	Australian Pine	ME	2ME		M	M		M	M
Cupressus sempervirens 'Pyramidalis' (O.Targ.Tozz.) Nyman	Italian Cypress	2ME	M 2E	M				2M 2E	
Eucalyptus camaldulensis Dehnh.	River Red Gum	ME						ME	
Gleditsia triacanthos L.	Honey Locust	M	M				M		
Ligustrum ovalifolium Hassk.	California Privet							2M	
Ligustrum vulgare L.	Common Privet							E	
Morus alba L.	White Mulberry							2ME	
Pinus brutia Ten.	Turkish Pine		M						
Pinus pinea L.	Stone Pine	2M 2E	2M 2E			E		2ME	
Platanus orientalis L.	Oriental Plane Tree	M	2ME					2M 2E	
Tilia cordata Mill.	Small-Leaved Lim	M	2M	M				ME	

Note: Obsevation Time: M (Morning), E (Evening); *Bird Species: *Sd* (*Streptopelia decaocto* Frivaldszky), *Cm* (*Corvus monedula* L.), *Cc* (*Corvus cornix* L.), *Pp* (*Pica pica* L.), *Fp* (*Ficedula parva* Bechstein), *Pm* (*Parus major* L.), *Pd* (*Passer domesticus* L.), *Ds* (*Dendrocopos syriacus* (Hemprich & Ehrenberg))

The Australian Pine attracted the highest number of bird species with 12 species, followed by the Turkish Pine with 11 species. Other plants that attracted the highest number of bird species were the Oriental Plane Tree with 8 species, and the Boxelder, Italian Cypress (Horizontal form), and Stone Pine with 6 species. Four of the six plant species that attracted the highest number of bird species were native species.

Native, resident, insectivorous and omnivorous birds show significant variance ($p<0.05$), depending on the location of the park, according to the results of the Mann Whitney U test. Depending on the location of the park, it has been determined that urban adapter and urban exploiter birds do not show significant variance. Native and urban adapter birds show significant variance between shrubs and trees; between broad-leaved and coniferous plants, native, urban adapter, urban exploiter, insectivorous and omnivorous birds show significant variance ($p<0.05$). Depending on the park location, plant species and the type of plant leaf, avian diversity shows a significant variance (*Table 7*). As there is no significant variance between native and exotic tree species and bird species and avian diversity, this is not included in the table.

The results of the Kruskal Wallis test are shown in *Table 8*, which shows bird species and avian diversity depending on the height of the plant. A statistically significant variance was observed between plant heights for native birds, omnivorous birds and levels of avian diversity, based on the test results ($p<0.05$). The level of attraction of native birds is much higher for high-sized plants than for short-sized plants; the level of attraction of native birds is significantly higher for medium-sized plants than short-sized

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plants. In attracting omnivorous birds from higher plants to shorter plants, there is a significant variance. More omnivorous birds than short plants are attracted by higher plants. There is a significant variance in avian diversity between the likelihood of finding more birds in high and medium-sized plants than in short-sized plants (*Table 8*).

Table 7. *Calculation results of Mann-Whitney U test on bird species and avian diversity related to park location, plant species and leaf type*

Bird Species	**Park Location**	**Mean Rank**	**U**	***p***
Native	Urban Center	25.09	524	0.025*
	Urban Fringe	34.78		
Resident	Urban Center	7.5	144	0.002*
	Urban Fringe	17.86		
Urban Adapter	Urban Center	20.46	337	0.096
	Urban Fringe	26.82		
Urban Exploiter	Urban Center	21.61	277	0.121
	Urban Fringe	25.29		
Insectivorous	Urban Center	10.71	177.5	0.008*
	Urban Fringe	19.34		
Omnivorous	Urban Center	21.77	471.5	0.002*
	Urban Fringe	34.08		
Avian Diversity	Urban Center	25.74	569	0.018*
	Urban Fringe	36.21		
Bird Species	**Plant Species**	**Mean Rank**	**U**	***p***
Native	Shrub	13.36	284.5	0.006*
	Tree	31.19		
Resident	Shrub	9.88	70.5	0.203
	Tree	15.82		
Urban Adapter	Shrub	8.5	109.5	0.041*
	Tree	24.55		
Urban Exploiter	Shrub	20	115	0.611
	Tree	23.38		
Insectivorous	Shrub	10.5	40	0.430
	Tree	16.38		
Omnivorous	Shrub	17.40	163	0.168
	Tree	27.47		
Avian Diversity	Shrub	12.64	303.5	0.003*
	Tree	32.34		
Bird Species	**Leaf Type**	**Mean Rank**	**U**	***p***
Native	Broad-leaved	25.53	133.5	0.003*
	Coniferous	40.73		
Resident	Broad-leaved	13.88	60.5	0.257
	Coniferous	17.94		
Urban Adapter	Broad-leaved	20.33	110	0.008*
	Coniferous	31.54		
Urban Exploiter	Broad-leaved	20.7	134.5	0.002*
	Coniferous	28.65		
Insectivorous	Broad-leaved	13.33	49	0.017*
	Coniferous	21.6		
Omnivorous	Broad-leaved	22.8	125.5	0.002*
	Coniferous	36.54		
Avian Diversity	Broad-leaved	25.72	122.5	0.000*
	Coniferous	43.75		

Note: * the significance level (p) <0.05

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Table 8. *Calculation results of Kruskal-Wallis test on bird species and avian diversity related to plant size*

Bird Species	Plant Size		Test Statistic	Std. Error	Std. Test Statistic	*p*	**Adjusted *p*
Native	Short	High	-16.393	5.250	-3.123	0.002	0.005*
	Short	Medium	-17.787	6.568	-2.708	0.007	0.020*
	High	Medium	1.394	5.581	0.250	0.803	1
Omnivorous	Short	High	-16.344	4.944	-3.306	0.001	0.003*
	Short	Medium	-8.500	5.981	-1.591	0.155	0.466
	Medium	High	-7.844	4.944	-1.586	0.113	0.338
Avian Diversity	Short	High	-17.080	5.292	-3.228	0.001	0.004*
	Short	Medium	-18.468	6.714	-2.750	0.006	0.018*
	High	Medium	1.388	5.781	0.240	0.810	1

Note: * the significance level (p) <0.05 and **significance values have been adjusted by the bonferroni correction for multiple tests

Discussion

Many birds are usually observed in urban environments. However, very few of them are native species (McCurdy, 2016). However, native species made up most bird species (11 species/68.75%) observed in the four urban parks examined in Aydin city.

The species common in urban landscapes are exotic exploiters or general native species tolerant to various urban conditions (White et al., 2005; Antos, 2006; McKinney, 2006). Resident species dominated the bird community in the city center and made up over 90% of the species observed. However, their number decreased as the building density decreased (McCurdy, 2016). All bird species observed in this study comprised urban adapter (5 exotic and 9 native species/87.5%) and urban exploiter (2 native species/12.5%) species. Resident species (11 species) made up most of the bird species observed (68.75%). However, they increased (towards the urban fringe) as the building density decreased.

The ratio of granivores in the bird community reaches a maximum in the city center (23%), and the ratio of the species in this group decreased towards natural regions and reached 8% (McCurdy, 2016). In this study, only one granivore species (Eurasian Collared-Dove) was identified. The number of insectivorous species with the highest ratio (56.25%) in the bird population increased towards natural areas.

In the studies investigating bird diversity in the USA (Tucson), Canada (Quebec), Germany (Leipzig), Scotland (St. Andrews), and Israel (Tel-Aviv), it was determined that the synanthropic species, including urban adapter and urban exploiter species such as the House Sparrow, Rock Dove (*Columba livia* Gmelin), Common Starling (*Sturnus vulgaris* L.), Eurasian Magpie (*Pica pica* L.), Eurasian Blackbird (*Turdus merula* L.), Hooded Crow, Eurasian Jackdaw, European Robin (*Erithacus rubecula* L.), and Great Tit, were the common bird species in cities (Shwartz et al., 2008; Strohbach et al., 2009; Carbó-Ramírez and Zuria, 2011; Camacho-Cervantes et al., 2018; Hensley et al., 2019). In this study, the Eurasian Collared-Dove, Eurasian Jackdaw, Hooded Crow, Great Tit, and House Sparrow were most frequently observed in the parks, and similar results were obtained.

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Similarly to the results of previous studies (White et al., 2005; Shwartz et al., 2008; Yang et al., 2015), the results also revealed that the woody plant species richness had a positive effect on bird species richness. Specific habitat characteristics that have been effective in increasing bird species diversity in urban green areas are tall tree woodlands and hollow old trees (Fernández-Juricic, 2004; Sandström et al., 2006; Stagoll et al., 2012; Threlfall et al., 2016). During the winter months, insectivorous species are more frequently observed in wider green areas with more tree and shrub species and in taller trees (Carbó-Ramírez and Zuria, 2011). Insectivorous bird species such as the Spotted Flycatcher (*Muscicapa striata* Pallas), Eurasian Blue Tit, Great Tit, Syrian Woodpecker [*Dendrocopos syriacus* (Hemprich & Ehrenberg)], and Eurasian Nuthatch were more frequently observed in tall coniferous trees, such as Atlas Cedar, Cedar of Lebanon (*Cedrus libani* A. Rich.), Italian Cypress (Horizontal form), Turkish Pine, and Stone Pine, and in tall broad-leaved trees such as the Tree of Heaven, Boxelder, Australian Pine, Southern Catalpa (*Catalpa bignonioides* Walt.), River Red Gum (*Eucalyptus camaldulensis* Dehnh.), White Mulberry, Oriental Plane Tree, Black Poplar (*Populus nigra* L.), and Black Locust in the Pinarbasi Recreation Area and Aytepe Recreation Area with more tree and shrub species and the wider area. Older and taller trees are more likely to have hollows compared to smaller trees (Carlson et al., 1998; Manning et al., 2006; Lindenmayer et al., 2014), and Woodpeckers, hollow-nesting species and forest birds increase from the city center to the periphery (Sandström et al., 2006). Under this view, the Eurasian Blue Tit, Syrian Woodpecker, and Eurasian Nuthatch, which are hollow-nesting species, were observed in the old and tall coniferous and broad-leaved trees in the Pinarbasi Recreation Area and Aytepe Recreation Area near the urban fringe.

There is a relationship between bird species richness and vegetation structure. The features of the vegetation structure are important for birds in urban areas (Lancaster and Rees, 1979; Mills et al., 1989; Fernández-Juricic, 2004). That the Eurasian Jay and Common Chaffinch (*Fringilla coelebs* L.) were observed in coniferous and broad-leaved tree species comprising the Boxelder, Australian Pine, Atlas Cedar, Italian Cypress (Horizontal form), White Mulberry, Turkish Pine, Stone Pine, Oriental Plane Tree, and Black Poplar supports the view that these bird species are observed in all kinds of woodlands (Bloomsbury, 2019).

The bird species richness in the Pinarbasi Recreation Area with more deciduous trees was found to be higher than the bird species richness in the Aytepe Recreation Area with more coniferous trees. This result is compatible with the view that the bird species richness is higher in parks where there are more deciduous trees than coniferous trees (Thompson et al., 1993). But it has been observed that the richness of coniferous trees for bird species is higher than broad-leaved trees.

Well-protected understory may provide birds with abundant hunting products such as arthropods (Kirchner, 1977; Conner et al., 1986; Keller et al., 2003). The abundant food source enabled the observation of the Eurasian Magpie, Great Tit, and House Sparrow in the shrubs formed by the Japanese Spindle Tree, California Privet, Common Privet, Japanese Pittosporum, and Four-Stamen Tamarisk that made up the understory. While the House Sparrow was observed in four of five shrub species, the Great Tit, the only insectivorous species among these species, was observed in the Japanese Spindle Tree and Common Privet. So, doubling the vegetation layers significantly increases the number of insectivorous bird species in particular (Threlfall et al., 2016).

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There is a significant relationship between bird diversity and the amount of natural vegetation (Sandström et al., 2006; Threlfall et al., 2016; Muñoz-Pedreros et al., 2018). The diversity of bird species increases as the vegetation increases towards the urban fringe (Blair, 1999; Sandström et al., 2006). Since vegetation is usually exotic, there is an increase in the diversity of exotic bird species. However, sometimes, native vegetation allows for a higher proportion of native bird species (White et al., 2005; Chace and Walsh, 2006; Daniels and Kirkpatrick, 2006; Threlfall et al., 2016). Although the variance in this study is not statistically significant, when consideration is given to observed bird species and plant species, the number of native bird species was found to be higher in the Pinarbasi Recreation Area and Aytepe Recreation Area on the urban fringe where there were more native tree species, which was due to the fact that high diversity in natural vegetation provided more nesting space, shelter, and food for many bird species (Chong et al., 2014).

The Grey Wagtail and Western Yellow Wagtail have specific habitat requirements; such as being observed only in open vegetative areas (Yang et al., 2015). Likewise, the White Wagtail (*Motacilla alba* L.), Grey Wagtail, and Western Yellow Wagtail were observed in open areas by the pool in the Pinarbasi Recreation Area and Nevzat BICER park.

The Eurasian Jackdaw, Hooded Crow, and House Sparrow were three of the most frequently observed species in all parks since they are omnivorous species, are not selective in terms of food, and are highly adapted to urban conditions. The Great Tit and Eurasian Collared-Dove, which are the other species most frequently observed in the parks, are highly adapted to urban conditions.

While the trees on which the birds were observed in the morning provide food, the trees on which the birds were observed in the evening provide shelter. The reason the Australian Pine, Turkish Pine, and Oriental Plane Tree in the Pinarbasi Recreation Area attracted the highest number of bird species is that they are usually a food source for birds. In the Pinarbasi Recreation Area, the Australian Pine and Turkish Pine also attract most bird species at night and provide them with shelter.

The Turkish Pine, which attracted the highest number of bird species in the Aytepe Recreation Area, offers food for all bird species and shelter for most of them. The Italian Cypress (Horizontal form) is another species that is mostly a food source for most of the bird species.

The reason the Silky Oak in Nevzat BICER park attracted the highest number of bird species is that it is mostly a food source for birds. The Boxelder, White Mulberry, and Japanese Pagoda Tree, other tree species on which the birds were mostly observed in the morning observations, are also mostly food sources for birds. The Boxelder and Russian Olive, on which bird species were mostly observed in the evening, mostly serve as a shelter for birds. Since the Silver Maple (*Acer saccharinum* L.) has a dense texture, it is used for spending the night by the House Sparrows. The dense leaves of the tree allow the birds to hide from predators at night.

In Ismet SEZGIN Park, the Australian Pine attracts the highest number of bird species because it is a food source for birds. The Italian Cypress (Pyramidal form), Stone Pine, Kurrajong, Oriental Plane Tree, and Small-Leaved Lime, other tree species on which the birds are mostly observed in the morning, are also food sources for birds. The Stone Pine and Italian Cypress (Pyramidal form), on which bird species are mostly observed in the evening, also serve as a shelter.

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The birds were intensely observed in the trees in the parks examined in the study because trees are more sheltered from attacks by predators such as cats because of their height. Small shrubs are rarely used as they leave birds vulnerable to attack by cats living in parks.

Conclusions

Understanding the relationships between biodiversity and urban green areas is important for the management and especially conservation of urban green areas (Temple and Wiens, 1989; Ives et al., 2016; Ibáñez-Álamo et al., 2017). To understand the vegetation and to associate it with wildlife activity and pattern in a particular area are considered to be the best approaches for predicting the species that can use a metropolitan area and their capacity (Morrison et al., 1992; Clergeau et al., 1998).

The relationship between native bird species and native plants was found to be higher compared to exotic plants (Donnelly and Marzluff, 2004; Daniels and Kirkpatrick, 2006). The heterogeneity of native vegetation makes up the best starting point for the conservation of native bird species diversity in urban environments and the minimization of urban exploiter and exotic species (Chace and Walsh, 2006; Palmer et al., 2008; Shwartz et al., 2008).

It is necessary to give priority to natural or semi-natural vegetation for the management of urban areas that support bird wildlife, and the species that require high maintenance should be considered as a second option (Chong et al., 2014). Rather than exotic woody species, different native plant species should be mainly used in urban parks because of their low water requirements and their compatibility with the soil structure and climate of the region (Livingston et al., 2003; Chace and Walsh, 2006; Daniels and Kirkpatrick, 2006; Burghardt et al., 2009). Native trees, shrubs, and groundcovers are very important since they are sources of food and nectar and attract many insects that birds feed on. Birds are fed with the seeds of these native plants and the insects they attract. Therefore, native plants are important parts of a wildlife park focusing on bird habitat (Bauer, 2012).

The ratio of shrubs and trees of different sizes should be increased in urban parks of Aydin to increase bird diversity. Native plant species that attract native bird species should be used in the planting design studies of the parks to be built in Aydin and other cities in Turkey and the world (*Table 9*).

While the White Mulberry and Turkish Pine should be used if the Eurasian Jay is desired to be invited to parks, the Italian Cypress (Horizontal form), Turkish Pine, and Oriental Plane Tree should be used if the Eurasian Magpie is desired to be invited, the Turkish Pine should be used if the Common Chaffinch is desired, the Stone Pine should be used if the Red-Breasted Flycatcher (*Ficedula parva* Bechstein) is desired to be invited, the Cedar of Lebanon, Turkish Pine, and Stone Pine should be used if the Spotted Flycatcher is desired, the Turkish Pine should be used if the Eurasian Blue Tit is desired to be invited, the White Mulberry, Turkish Pine, and Oriental Plane Tree should be used if the great tit is desired to be invited, the Turkish Pine and Oriental Plane Tree should be used if the Syrian Woodpecker is desired, and the Turkish Pine and Stone Pine should be used if the Eurasian Nuthatch is desired to be invited.

The Turkish Pine, Oriental Plane Tree, Italian Cypress (Horizontal form), Stone Pine, and White Mulberry should be planted in parks as food sources for the Eurasian Jay,

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Great Tit, Eurasian Magpie, Eurasian Blue Tit and Common Chaffinch, Spotted Flycatcher and Syrian Woodpecker.

Table 9. *Native plant species that attract bird species in parks (developed from Bradbury, 2019)*

Plant Types	Family	Plants	Provides
Ground cover	*Fabaceae*	*Lupinus albus* L.	Insects
	Lamiaceae	*Lavandula stoechas* L.	Seeds
	Urticaceae	*Urtica dioica* L.	Insects, seeds
	Araliaceae	*Hedera helix* L.	Berries, insects, shelter
	Grossulariaceae	*Ribes orientale* Desf.	Berries, insects, shelter
	Santalaceae	*Viscum album* L.	Berries, insects, shelter
Shrub	*Adoxaceae*	*Sambucus nigra* L.	Berries, insects, shelter
		Viburnum lantana L.	Berries, insects
		Viburnum opulus L.	Berries, insects, shelter
	Aquifoliaceae	*Ilex aquifolium* L.	Berries, insects, shelter
	Betulaceae	*Corylus avellane* L.	Insects, seeds, shelter
	Ericaceae	*Arbutus unedo* L.	Fruit, insects, shelter
	Oleaceae	*Ligustrum vulgare* L.	Fruit, shelter, insects
	Rhamnaceae	*Rhamnus cathartica* L.	Fruit, insects, shelter
	Rosaceae	*Crataegus monogyna* Jacq.	Berries, insects, shelter
		Rosa canina L.	Fruit, insects, shelter
		Prunus avium L.	Fruit, shelter, insects
		Prunus laurocerasus L.	Berries, insects, shelter
		Pyracantha coccinea M. Roem.	Fruit, shelter
		Pyrus communis L.	Fruit, insects, shelter
		Sorbus acuparia L.	Berries, insects, shelter
		Sorbus torminalis (L.) Crantz.	Berries
Tree	*Styracaceae*	*Styrax officinalis* L.	Berries, insects, shelter
	Taxaceae	*Taxus baccata* L.	Fruit, insects, shelter
	Cornaceae	*Cornus mas* L.	Fruit, shelter, insects
	Cupressaceae	*Cupressus sempervirens* 'Horizontalis' (Mill.) Loudon	Fruit, insects, shelter
	Elaeagnaceae	*Elaeagnus angustifolia* L.	Fruit, insects, shelter
	Lauraceae	*Laurus nobilis* L.	Fruit, shelter, insects
	Moraceae	*Morus alba* L.	Fruit, shelter, insects
	Pinaceae	*Cedrus libani* A.Rich.	Insects, seeds, shelter
		Pinus brutia Ten.	Fruit, insects, shelter
		Pinus pinea L.	Fruit, insects, shelter
	Platanaceae	*Platanus orientalis* L.	Insects, seeds, shelter
	Salicaceae	*Populus alba* L.	Insects, seeds, shelter
		Populus nigra L.	Insects, seeds, shelter
		Salix alba L.	Insects, shelter

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The Italian Cypress (Horizontal form), Russian Olive, Turkish Pine, White Mulberry, Stone Pine, and Oriental Plane Tree should be used in the planting of parks since they provide shelter for the Great Tit, Spotted Flycatcher, Eurasian Jay, Common Chaffinch, Red-Breasted Flycatcher, Eurasian Blue Tit, Eurasian Nuthatch, and Syrian Woodpecker.

Rather than being an aesthetic element, parks should be a network of life where nature is imitated and a mini-ecosystem in which birds, bees, insects, and other creatures live. Thus, parks that support wildlife will also increase bird diversity (Bauer, 2012).

The planting design should be included in future studies if it is aimed to protect high natural biodiversity in urban parks.

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