



The effects of recreation on the forest bird community in the North of Iran (Case study: Alangdareh Forest, Gorgan)

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Article Info	Abstract
Article type: Research Article	Human population growth and increasing needs are causing significant environmental damage and disrupting natural processes. Industrialization has particularly contributed to ecosystem destruction, intensifying demands for recreational areas and thereby posing threats to protected zones and wildlife populations. Human activities and recreation also detrimentally affect ecosystems and forest bird populations. To investigate these impacts, two distinct forest zones were studied: Shastkalateh Protected Forest as a control and Alangdareh Recreational Forest as a treatment area. Bird species density and their relationship with environmental factors were assessed using point-count sampling method. Data collected over a year from 100 survey points within each 25-meter radius revealed significant differences in bird species composition, density, and diversity between the two areas. Analysis of Similarity (ANOSIM) confirmed a substantial distinction ($P=0.001$) between Alangdareh Recreational Forest and Shastkalateh Protected Forest. Bird density, diversity, and species composition were notably higher in the protected forest, supported by SIMPER results and redundancy analysis. Habitat correlations identified two distinct bird species groups: one associated with specific features like rock cover in the recreational forest (e.g., Common Chiffchaff, Eurasian Golden Oriole) and another linked to characteristics such as dead tree decay and large snags in the protected forest (e.g., Brambling, European Robin). Overall, this research underscores the negative impact of recreational activities on bird communities in Alangdareh Recreational Forest compared to the more pristine conditions of Shastkalateh Protected Forest, highlighting higher bird density and diversity in undisturbed virgin forests.
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Introduction

The expansion of cities due to population growth is one of the major reason for the loss of biodiversity in habitats, which negatively affects green spaces and environmental quality. Despite these challenges, urbanization continues to increase the demand for recreational areas and protected spaces (Worboys et al., 2001; Buckley, 2002; Stagnol et al., 2010; Hindayani and Mardikaningsih, 2022). In recent decades, there has been a notable rise in outdoor recreational activities such as hiking, cycling, skiing, and snowshoeing, particularly in protected areas, which collectively receive approximately 8 billion visits annually worldwide (Balmford et al., 2015). These activities depend on specific infrastructure like hiking trails and ski slopes (De Groot et al., 2010; Paracchini et al., 2014), and research consistently emphasizes their positive impacts on health, stress reduction, and overall well-being (Godbey, 2009; Buchecker and Degenhardt, 2015). This increasing popularity underscores the role of urban parks as essential spaces for outdoor recreation, offering city residents opportunities for natural experiences that enhance their health and well-being (Kaczynski and Henderson, 2007; Chiesura, 2004). Urban green spaces are crucial for recreation within city ecosystems. Numerous studies have highlighted their positive effects, including local climate regulation (Qiu et al., 2017), reduction of noise and air pollution (Song et al., 2018), and their role in enhancing urban environments while fulfilling residents' daily leisure needs (Sugiyama et al., 2008). Green spaces provide vital ecosystem services for both sustainable cities and people (Zhou et al., 2018). Although recreation is not the primary threat to global biodiversity, it often occurs in protected areas designated for species conservation, potentially resulting in disproportionate impacts. However, nature-based recreation plays a vital role in promoting human health and fostering connections with nature, which can encourage pro-environmental behaviors (Cooper et al., 2015). Understanding the effects of outdoor recreation on wildlife is crucial for wildlife management, as recreational activities can disrupt wildlife

similarly to natural predators (Frid and Dill, 2002).

The utilization of forests, parks, and conservation areas for recreation has significantly increased, raising concerns about its ecological impacts (Cordell et al., 2008; Balmford et al., 2009). Activities such as trampling during migrations can degrade vegetation and alter species compositions towards more resilient types (Cole and Monz, 2002; Ballantyne and Pickering, 2015; Pickering and Barros, 2015). Leisure and tourism often lead to disturbances like vegetation damage, soil erosion, and various forms of pollution, affecting ecosystem processes and wildlife behaviors such as habitat use, foraging, and reproduction (Monz et al., 2013; Hammitt et al., 2015; Buxton et al., 2017; Gutzwiller et al., 2017). Additionally, nature-based tourism poses significant threats to endangered plant species and influences the dynamics of plant communities (Barros et al., 2015; Wraith and Pickering, 2017).

Forests host a substantial portion of global biodiversity (Coote et al., 2013). The primary threat to biodiversity lies in the loss and extensive transformation of naturally dynamic forests, largely driven by competing land uses (Angelstam and Donz-Breuss, 2004). Avian communities within forest ecosystems serve as crucial indicators of habitat quality and are widely used for biodiversity assessments across Europe (Gao et al., 2015; Gregory and van Strien, 2010). Birds play crucial roles in ecosystems, fulfilling vital functions such as seed dispersal, pollination, herbivory, and predation (Peh et al., 2005). Monitoring bird populations involves assessing parameters like species richness, evenness, abundance, diversity, and density (Zakaria and Rajpar, 2013). Their unique biological characteristics enable birds to contribute significantly to natural processes and human activities, including pest control, rodent management, and seed dispersal (Rey Benayas et al., 2017; Carvalho et al., 2020; Simonov and Matantseva, 2020). Additionally, birds serve as indicators of environmental health, responding to human impacts by adjusting nesting behaviors and ecological group

diversity (Lebedinskii et al., 2019; Kuznetsova, 2021).

The research highlights several important aspects about birds and their habitat preferences. Species specialized for indoor environments rely on resources found within forests, while those adapted to forest edges utilize and adapt to these transitional habitats (Zakaria et al., 2014). Insectivorous birds, particularly those specialized for indoor habitats, are disproportionately affected by forest fragmentation and edge effects (Sodhi et al., 2004; Zakaria et al., 2014). Undisturbed forest habitats are crucial as shelters for birds that depend on these environments (Nor Hashim and Ramli, 2013). The structure of forests, including diversity and density of vegetation, plays a critical role in supporting bird diversity by providing essential resources for nesting and food (Khera et al., 2009). Researchers worldwide have explored how environmental variables, particularly forest structure, influence the distribution and abundance of bird species (Reich et al., 1999). Habitat also influences the daily activity patterns of small passerines, influencing behaviors related to foraging and predator avoidance (McCabe and Olsen, 2015; Reyes-Arriagada et al., 2015). Birds often adjust their activity patterns to balance food availability and predation risk, showing varied behaviors across different habitat types (Bednekoff and Houston, 1994; Macleod et al., 2005; McNamara et al., 1994; Reyes-Arriagada et al., 2015).

The impact of recreational activities on wildlife is a critical concern, particularly due to birds' sensitivity to habitat characteristics like vegetation cover, which makes them valuable indicators for habitat monitoring (Larson et al., 2016). Understanding the thresholds at which recreational activities affect species, positively or negatively, is essential for effectively managing protected areas. Researchers stress the need to move beyond simple hypothesis testing to identify specific disturbance thresholds that influence recovery processes. While habituation to human presence can mitigate behavioral responses, it may increase vulnerability to

predation or human-wildlife conflicts (Baudains and Lloyd, 2007; Geffory et al., 2015; Bejder et al., 2009). Animals may alter their habitat use patterns over time to minimize disturbance, affecting population dynamics and community structure (Lesmerises et al., 2018; Botsch et al., 2017; Reed and Merenlender, 2008; Kangas et al., 2010). However, research outcomes vary widely across ecosystems and taxa, underscoring the need for systematic reviews and meta-analyses to synthesize findings and establish generalized impacts (Larson et al., 2016; Haddaway, 2015). Such comprehensive approaches are crucial for informing evidence-based management decisions and developing effective conservation strategies amidst increasing recreational pressures on protected areas globally (Schulze et al., 2018).

Materials and Methods

Study area

The Alangdareh Forest Park extends from 54° 26' 7" to 54° 7' 30" North latitude and from 36° 47' 36" to 36° 48' 36" East longitude, with elevations ranging from 300 m to 480 m above sea level. It is located within the Ziarat forestry plan and the 2nd series of Naharkhoran, covering an area of 185 hectares. The park measures up to 2750 meters in length and 875 meters in width (Barze Kar, 2003). The Control Study Area, Shastkalateh Educational Research Forest, is situated 8 km southwest of Gorgan. This forest spans over 3716 hectares, divided into two series. The first series consists of 33 parcels totaling 1731.3 hectares, while the second series includes 31 parcels covering 1992 hectares. The first series is located between 36° 43' 30" to 36° 42' 30" North latitude and 54° 21' 6" to 54° 23' 30" East longitude, with elevations ranging from 210 m to 995 m above sea level (Moiery and Mohammad Alipour Malekshah, 2006). The second series of Shastkalateh Forest spans from 36° 43' 30" to 36° 42' 30" North latitude and from 54° 21' 6" to 54° 23' 30" East longitude, with elevations varying from 250 m to 1935 m above sea level (Moiery and Mohammad Alipour Malekshah, 2006).

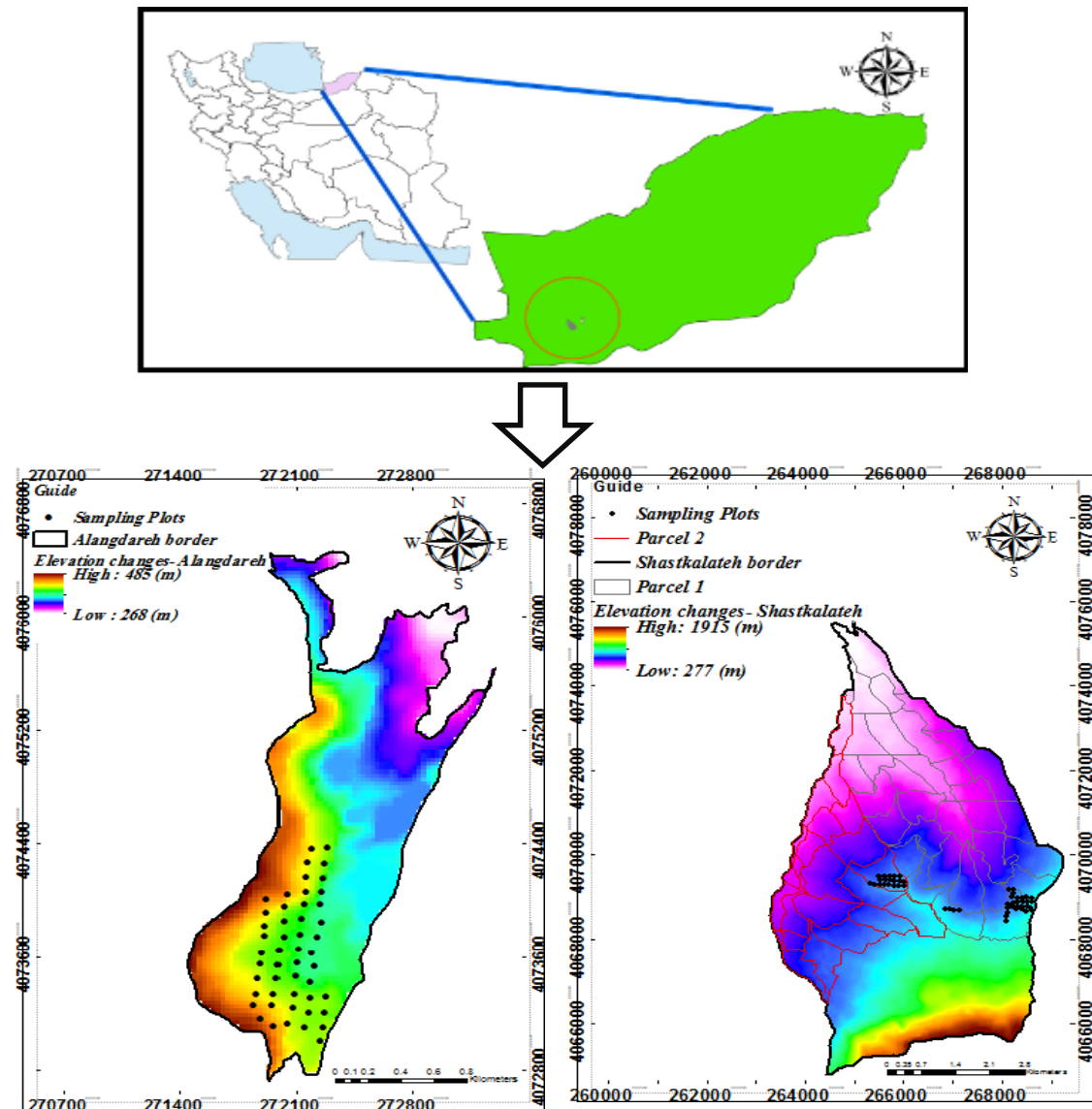


Figure 1. The location of the study region in Iran – Golestan Province.

Research method

Sampling of birds and environmental variables

Bird sightings and habitat variables were recorded over one year at 100 survey points, each within a 25-meter radius (Watson et al., 2004). The survey sites were located in the protected areas of Alangdareh and Shastkalateh. Point counting was used for bird sampling (Legendre and Legendre, 1998), with a standardized 5-minute stop at each point to ensure sampling accuracy and safety (Brand and George, 2001). Birds were then observed for an additional 10 minutes following the rest period (Atkinson, 2003). Data on birds and environmental variables

were collected within a 25-meter radius of each survey point (Castelletta et al., 2005), a distance chosen due to the challenges of bird identification beyond this range in forest environments. Fieldwork was conducted from sunrise to 10 AM under favorable weather conditions without rain or storms (Vareste, 2011). Environmental variables included metrics such as litter depth, canopy cover density, percentage of grass and stone cover, log decay stage, tree diameter at breast height (dbh), tree height, number of standing dead trees, temperature, and humidity.

Data analysis

Distance 7 software was utilized to calculate

bird density. Additionally, CANOCO software was employed to investigate the relationship between bird abundance and habitat variables. Prior to ordination analysis in CANOCO, gradient lengths were measured for redundancy analysis (RDA) and canonical correspondence analysis (CCA). These gradient lengths represent beta diversity in community composition. Generally, if the gradient length is less than 3, the linear method is preferred. Since the beta gradient length was less than 3 in this research, redundancy analysis (RDA) was selected. Furthermore, CAP4 software was used to analyze bird diversity. Analysis of similarity (ANOSIM) was employed to assess differences in bird species composition between the two regions. Similarity

percentage (SIMPER) was used to determine species density and dominance in different habitats. To analyze the pattern of bird species composition between Shastkalateh Forest and Alangdareh Recreational Forest Park, both Analyses of Similarity (ANOSIM) and Similarity Percentage (SIMPER) were conducted.

Results

Bird observations were recorded in the Shastkalateh Protected Forest area and Alangdareh Recreational Forest Park. In the Shastkalateh Forest area, 963 bird observations were made across 28 species. Similarly, in the Alangdareh Forest Park area, 657 bird observations were recorded spanning 23 species (see Figure 2, Figure 3 and Table 1).

Table 1. The number of bird individuals detected in forest plots.

Scientific name	English name	Number of Individuals	
		Shastkalateh Forest	Alangdareh Forest Park
<i>Turdus merula</i>	Blackbird	74	32
<i>Turdus ruficollis</i>	Black-throated Thrush	3	2
<i>Dryocopus martius</i>	Black Woodpecker	10	0
<i>Fringilla montifringilla</i>	Brambling	69	42
<i>Cettia cetti</i>	Cetti's Warbler	63	16
<i>Parus ater</i> (<i>Parus ater</i>)	Coal Tit	117	130
<i>Dendrocopos major</i>	Great Spotted Woodpecker	61	29
<i>Parus major</i>	Great Tit	135	66
<i>Columba palumbus</i>	Common Wood Pigeon	12	0
<i>Aegithalos caudatus</i>	Long-tailed Tit	3	12
<i>Sitta europaea</i>	Eurasian Nuthatch	111	38
<i>Erithacus rubecula</i>	European Robin	119	37
<i>Turdus philomelos</i>	Song Thrush	39	3
<i>Troglodytes troglodytes</i>	Winter Wren	37	3
<i>Turdus viscivorus</i>	Mistle Thrush	5	0
<i>Fringilla coelebs</i>	Common Chaffinch	35	95
<i>Corvus cornix</i>	Hooded Crow	0	123
<i>Phylloscopus collybita</i>	Common Chiffchaff	1	5
<i>Dendrocopos minor</i>	Lesser Spotted Woodpecker	18	3
<i>Certhia familiaris</i>	Eurasian Tree creeper	8	1
<i>Ficedula parva</i>	Red-breasted Flycatcher	13	2
<i>Turdus iliacus</i>	Redwing	4	0
<i>Picus viridis</i>	European Green Woodpecker	4	0
<i>Luscinia megarhynchos</i>	Common Nightingale	9	2
<i>Phoenicurus phoenicurus</i>	Common Redstart	1	0
<i>Garrulus glandarius</i>	Eurasian Jay	1	0
<i>Dendrocopos syriacus</i>	Syrian Woodpecker	4	0
<i>Cuculus canorus</i>	Common Cuckoo	5	0
<i>Carduelis chloris</i>	European Greenfinch	0	6
<i>Passer domesticus</i>	House Sparrow	0	5
<i>Oriolus oriolus</i>	Eurasian Golden Oriole	0	3
<i>Sylvia atricapilla</i>	Blackcap	0	2
<i>Muscicapa striata</i>	Spotted Flycatcher	2	0

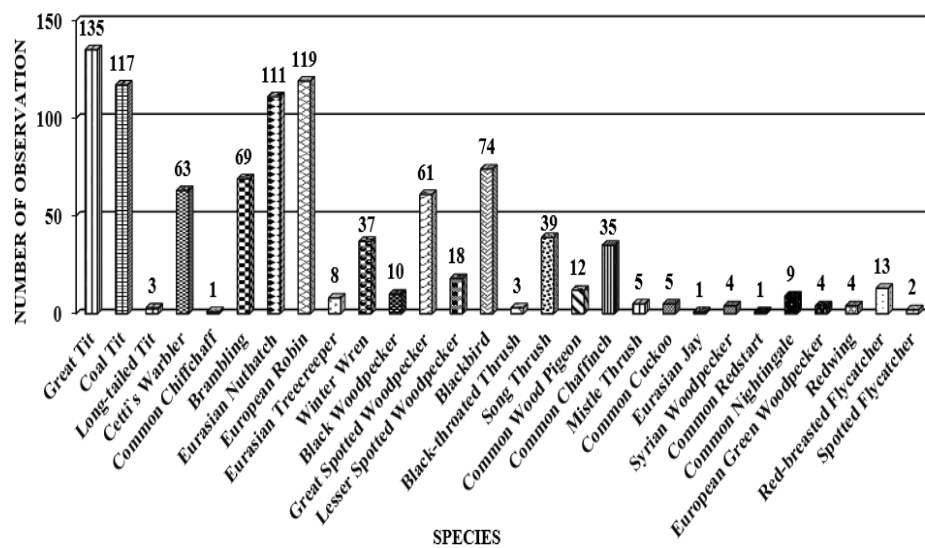


Figure 2. The abundance and number of bird species observations in the Shastkalateh Forest.

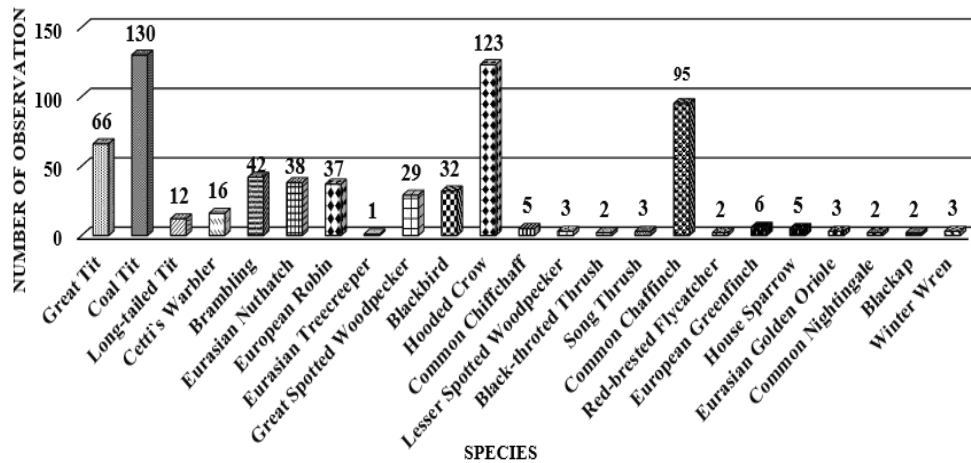


Figure 3. The abundance and number of bird species observations in the Alangdareh Forest Park.

According to Table 2, in Alangdareh Forest Park area, 67% of the species composition was accounted for by three common species: Common Chaffinch, Coal Tit, and Great Tit. Among these, the Common Chaffinch had the highest percentage of species composition and the highest density among all birds at 31.7094%. Additionally, the Common Chaffinch was identified as the dominant species in this area.

In Shastkalateh Forest, more than 49% of the species composition was attributed to three species: European Robin, Great Tit, and Coal Tit. Here, the European Robin had the largest share in species composition and the highest density among the birds, accounting for 18.4885%. Furthermore, the European Robin was recognized as the dominant species in this forest area. Moreover, there was a significant difference between Shastkalateh Forest and Alangdareh Forest Park ($P=0.001$).

Table 2. Analysis of the similarity percentage (SIMPER) for species composition of forest birds in Alangdareh Forest Park and Shastkalateh Forest.

Name of the species	Ave. abundance	Ave. similarity	contribution %	Cumulative %
Alangdareh				
Common Chaffinch	1.9	7.78772	31.7094	31.7094
Coal Tit	2.6	6.24356	25.422	57.1314
Great Tit	1.32	2.50537	10.2011	67.3326
Blackbird	0.64	1.92106	7.822	75.1546
European Robin	0.74	1.90646	7.76257	82.9171
Eurasian Nuthatch	0.76	1.40458	5.71907	88.6362
Hooded Crow	2.46	1.34216	5.4649	94.1011
Shastkalateh				
Erithacus rubecula	2.38	6.64912	18.4885	18.4885
Great Tit	2.7	6.21473	17.2806	35.769
Coal Tit	2.34	4.95492	13.7776	49.5466
Eurasian Nuthatch	2.22	4.06009	11.2894	60.836
Great Spotted Woodpecker	1.22	3.33466	9.27232	70.1084
Blackbird	1.48	2.67684	7.44318	77.5515
Cetti's Warbler	1.26	2.05475	5.7134	83.2649
Brambling	1.38	1.63377	4.54283	87.8078
Song Thrush	0.78	1.26051	3.50496	91.3127

Table 3. Estimation of average bird density (One per hectare $\pm$ Standard deviation) in Shastkalateh Forest and Alangdareh Forest Park.

Name of the species	Ave. density per hectare $\pm$ standard deviation		Model used	
	different season of the year- Alangdareh Forest Park	different season of the year- Shastkalateh Forest	different season of the year- Alangdareh Forest Park	different season of the year Shastkalateh Forest
Blackbird	3.26 $\pm$ 0.738	10.90 $\pm$ 2.37	Uniform/Cosine	Hazard/Cosine
Black-throated Thrush	0.565 $\pm$ 0.395	0.394 $\pm$ 0.222	Uniform/Cosine	Uniform/Cosine
Black Woodpecker	0	1.105 $\pm$ 0.386	-	Uniform/Cosine
Brambling	19.501 $\pm$ 10.191	32.617 $\pm$ 9.008	Uniform/Cosine	Hazard/Cosine
Cetti's Warbler	11.020 $\pm$ 8.857	27.210 $\pm$ 16.328	Hazard/Cosine	Hazard/Cosine
Coal Tit	56.120 $\pm$ 13.075	53.331 $\pm$ 11.290	Hazard/Cosine	Hazard/Cosine
Great Spotted Woodpecker	3.205 $\pm$ 1.048	9.768 $\pm$ 9.090	Uniform/Polynomial	Half-normal/Cosine
Great Tit	28.964 $\pm$ 7.637	44.234 $\pm$ 6.887	Uniform/Cosine	Uniform/Polynomial
Common Wood Pigeon	0	1.909 $\pm$ 1.171	-	Uniform/Polynomial
Long-tailed Tit	11.160 $\pm$ 11.282	0.477 $\pm$ 0.352	Hazard/Cosine	Uniform/Cosine
Eurasian Nuthatch	15.087 $\pm$ 4.017	35.873 $\pm$ 7.856	Uniform/Cosine	Hazard/Cosine
European Robin	11.514 $\pm$ 2.746	62.027 $\pm$ 10.408	Uniform/Cosine	Hazard/Cosine
Song Thrush	0.848 $\pm$ 0.479	4.310 $\pm$ 0.860	Uniform/Cosine	Uniform/Polynomial
Winter Wren	3.897 $\pm$ 2.880	23.352 $\pm$ 7.428	Uniform/Polynomial	Hazard/Cosine
Mistle Thrush	0	0.552 $\pm$ 0.236	-	Uniform/Cosine
Common Chaffinch	34.637 $\pm$ 5.711	8.625 $\pm$ 2.315	Uniform/Cosine	Uniform/Cosine
Hooded Crow	63.882 $\pm$ 33.154	0	Half-normal/Cosine	-
Common Chiffchaff	4.973 $\pm$ 2.561	2.546 $\pm$ 2.546	Uniform/Polynomial	Uniform/Polynomial
Lesser Spotted Woodpecker	1.909 $\pm$ 1.079	1.989 $\pm$ 0.736	Uniform/Cosine	Uniform/Cosine
Eurasian Tree creeper	4.547 $\pm$ 4.547	1.114 $\pm$ 0.455	Half-normal/Polynomial	Uniform/Polynomial
Red-breasted Flycatcher	0.497 $\pm$ 0.497	5.132 $\pm$ 2.046	Uniform/Polynomial	Uniform/Cosine
Redwing	0	0.442 $\pm$ 0.214	-	Uniform/Cosine
European Green Woodpecker	0	0.481 $\pm$ 0.233	-	Uniform/Polynomial
Common Nightingale	1.989 $\pm$ 1.392	1.183 $\pm$ 0.447	Uniform/Polynomial	Uniform/Polynomial
Common Redstart	0	3.183 $\pm$ 3.183	-	Half-normal/Polynomial
Eurasian Jay		1.989 $\pm$ 1.989	-	Half-normal/Cosine
Syrian Woodpecker	0	0.636 $\pm$ 0.0309	-	Uniform/Polynomial
Common Cuckoo	0	0.795 $\pm$ 0.409	-	Uniform/Cosine
European Greenfinch	1.178 $\pm$ 0.666	0	Uniform/Polynomial	-
House Sparrow	2.630 $\pm$ 1.354	0	Uniform/Polynomial	-
Eurasian Golden Oriole	0.305 $\pm$ 0.172	0	Uniform/Polynomial	-
Blackcap	0.649 $\pm$ 0.649	0	Uniform/Cosine	-

Spotted Flycatcher	0	0.649 ± 0.454	-	Uniform/Polynomial
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Data analysis was conducted to calculate the bird density of 28 species in the Shastkalateh Protected Forest region and 23 species in Alangdareh Forest Park. Birds exhibited varying density patterns. Table 3 displays the density of each bird species in both the Shastkalateh Protected Forest and Alangdareh Forest Park. In the Shastkalateh Protected Forest, the European Robin showed the highest density per hectare (62.027 ± 10.408), while the Black-throated Thrush had the lowest density per hectare (0.394 ± 0.222). Conversely, in Alangdareh Forest Park, the Hooded Crow exhibited the highest density (63.882 ± 33.154), and the Eurasian Golden

Oriole had the lowest density per hectare (0.305 ± 0.172).

Ordination and correspondence analysis of bird's community

According to Table 4, redundancy analysis was used to examine the relationship between forest bird communities and environmental variables. The results reveal a strong correlation between the abundance of bird communities and these environmental factors. The ordination of all species showed significant gradients across environmental variables. Table 4 presents the ordination of birds based on these environmental variables.

Table 4. Redundancy analysis of bird species in the two forest regions of Shastkalateh Forest and Alangdareh Forest Park.

Phrase	Axes				Total
	1	2	3	4	1.000
Eigenvalues	0.162	0.050	0.034	0.031	
Species- environment correlations	0.609	0.563	0.659	0.632	
Cumulative percentage variance of species data	16.2	21.2	24.6	27.7	
Cumulative percentage variance of species-environment relation	50.7	66.3	76.8	86.5	
Sum of all canonical eigenvalues					0.320

According to Table 4, there is a strong correlation between the abundance of bird communities and environmental variables. The first two axes explain 21.2% of the variation in species data that can be attributed to environmental factors. Furthermore, the correlation between bird species and environmental variables for these first two axes was 60.9% and 56.3%, respectively. This correlation indicates how well environmental variables explain the composition of bird communities. In Figure 3, the first axis of redundancy analysis separates Shastkalateh Forest from Alangdareh Forest Park, with the two main axes showing the greatest changes in the community structure. The first axis divides the bird community into two main groups. The first group includes House Sparrow, Long-tailed Tit, Chaffinch, European Greenfinch, Eurasian Golden Oriole, Eurasian Jay, Common Chiffchaff, and Hooded Crow, which show a positive correlation with rock cover in the Alangdareh Forest Park area (Figure 4). Among these,

Hooded Crow exhibits the strongest positive correlation with rock cover. The second group consists of Brambling, European Robin, Great Spotted Woodpecker, Coal Tit, Eurasian Treecreeper, Cetti's Warbler, Woodpigeon, Great Tit, Lesser Spotted Woodpecker, Syrian Woodpecker, Winter Wren, Song Thrush, Common Nightingale, Red-breasted Flycatcher, Redwing, Black Woodpecker, and Eurasian Nuthatch. This group shows a positive correlation with grass cover, log decay degree, number of logs over 15 m in height, litter depth, number of logs with diameter at breast height (dbh) between 50-100 cm, number of snags with dbh over 100 cm, canopy cover density, and number of logs 7-15 m in height in Shastkalateh Forest. Winter Wren, Red-breasted Flycatcher, European Robin, and Common Nightingale exhibit the strongest positive correlations with grass cover, litter depth, and log decay degree in this area. Litter depth, grass cover, log decay degree, and number of snags with dbh over 100 cm significantly influence the

density of these species compared to other habitat variables. Additionally, Winter Wren, Red-breasted Flycatcher, Coal Tit, Cetti's Warbler, European Robin, and Common Nightingale show a positive correlation with litter depth. Great Spotted Woodpecker,

Lesser Spotted Woodpecker, Black Woodpecker, Brambling, and Eurasian Nuthatch are positively correlated with the number of snags with dbh over 100 cm, canopy cover density, and number of snags with dbh between 20-50 cm.

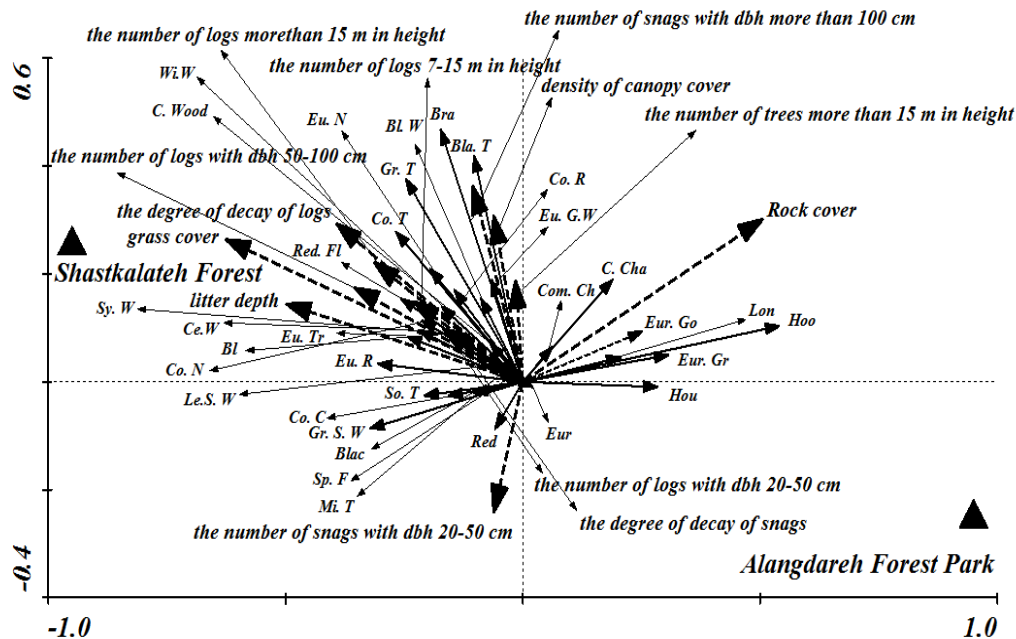


Figure 4. Redundancy correspondence analysis of bird species and environmental variables in the two forest regions of Shastkalateh Forest and Alangdareh Forest Park.

Eur: Eurasian Jay. Hou: House Sparrow. Eur. Gr: European Greenfinch. Hoo: Hooded Crow. Lon: Long-tailed Tit. Red: Redwing. Eur. Go: Eurasian Golden Oriole. C. Cha: Common Chaffinch. Com. Ch: Common Chiffchaff. Eu. G. W: European Green Woodpecker. Co. R: Common Redstart. Eu. N: Eurasian Nuthatch. Bla. T: Black-throated Thrush. Bra: Brambling. Mi. T: Mistle Thrush. Sp. F: Spotted Flycatcher. Blac: Blackcap. Gr. S. W: Great Spotted Woodpecker. Co. C: Common Cuckoo. So. T: Song Thrush. Eu. R: European Robin. Le. S. W: Lesser Spotted Woodpecker. Co. N: Common Nightingale. Bl: Blackbird. Eu. Tr: Eurasian Treecreeper. Ce. W: Cetti's Warbler. Sy. W: Syrian Woodpecker. Co. T: Coal Tit. Red. Fl: Red-breasted Flycatcher. Bl. W: Black Woodpecker. Gr. T: Great Tit. C. Wood: Common Wood Pigeon. Wi. W: Winter Wren.

Discussion

The study conducted in Golestan Province and compared bird communities between Shastkalateh Protected Forest and Alangdareh Recreational Forest Park. We found higher bird density, species diversity, and composition in the more intact Shastkalateh Protected Forest. The study highlighted significant negative impacts of recreation on bird communities in Alangdareh Recreational Forest Park. In contrast, Shastkalateh Protected Forest hosted more diverse bird species throughout the seasons. The study identified the most densely populated bird species in these two distinct forest areas: Shastkalateh Protected Forest and Alangdareh Recreational Forest Park. In Shastkalateh Protected Forest, the European Robin predominated across different seasons, indicating high density and dominance. On the other hand, the Hooded Crow, Coal Tit, and Common Chaffinch were dominant in Alangdareh Recreational Forest Park.

Specifically, the Common Chaffinch was noted for its highest density and dominance among all species there. Woodpeckers, Eurasian Nuthatch, and Wren were identified as dependent species in the central forest area, showing a positive correlation with various structural elements such as the decay of logs and snags, density of canopy cover, and characteristics of trees like height and diameter. This indicates that these species rely on specific forest structures for nesting, cover, and food sources. Overall, the study emphasizes the critical relationship between forest structure and bird diversity and abundance, as demonstrated in the Shastkalateh Protected Forest (Lohr et al., 2002).

Ruczynski et al. (2005) emphasize the critical role of biodiversity in maintaining the resilience of forest ecosystems. Biodiversity is fundamental for ensuring the adaptability of communities and the sustainable provision of ecosystem services, as highlighted by the Millennium Ecosystem Assessment (MEA, 2005) and Proenca et al. (2010). Biodiversity encompasses various spatial scales and includes components related to forest structure (e.g., tree dimensions, canopy complexity, deadwood, undergrowth), composition (e.g., diversity within and between species or communities), and function (e.g., succession, decomposition, nutrient cycling), as outlined by Canadian Forest Service (1995) and Ferris et al. (2000).

Indicators of forest structure are crucial for assessing biodiversity, focusing on the relationship between habitat characteristics and the abundance of forest-dwelling taxa, as noted by Lindenmayer et al. (2000) and McElhinny et al. (2006). Examples of such structural indicators include the frequency of uprooted trees (Angelstam and Donz-Breuss, 2004) and the quantity, quality, and diversity of deadwood (Lassauce et al., 2011). These indicators help gauge the health and diversity of forest ecosystems, essential for their conservation and sustainable management.

Deadwood plays a crucial role in biodiversity by serving as habitat for insects, influenced by interactions with fungi and microclimatic conditions (Wallace, 1869; Weslien et al.,

2011; Kostanjsek et al., 2018). Specific types of deadwoods support specialized insect and fungal associations, benefiting species like the Hermit beetle and white-backed woodpecker (Ranius and Hedin, 2001; Martikainen et al., 1998). Moreover, forests with abundant deadwood exhibit higher bat species richness (Tillon et al., 2016), while deadwood and mature trees provide essential shelter and nesting sites for forest birds and mammals (Lindenmayer and Ough, 2006). This promotes biodiversity at higher trophic levels by enhancing food availability, accessibility, and habitat suitability (Kortmann et al., 2018). Deadwood microhabitats on old-growth trees further support diverse ecosystem services for various forest taxa (Larrieu et al., 2018; Michel and Winter, 2009; Paillet et al., 2017). Furthermore, the abundance of tree microhabitats provided by living habitat trees is considered a valuable indicator of stand-level biodiversity (e.g., Larrieu et al., 2014; Winter and Muller, 2008). Tree microhabitats provide substrate and shelter for multiple taxa, including structural features such as cavities, dead crown wood, mistletoe, cracks, nests, and epiphytes, among others (Larrieu et al., 2018; Paillet et al., 2018). Conserving the diversity of tree microhabitats in sufficient abundance supports various species, making it crucial for maintaining biodiversity, especially invertebrates and fungi. It can also accelerate the recovery of ecosystem functions after disturbance and forest management measures (Franklin, 1989; Simonsson et al., 2015).

Conserving and maintaining biodiversity is considered crucial for supporting the density of forest birds, particularly species sensitive to changes and disruptions that depend on the core and more pristine areas of forest ecosystems. Woodpeckers and nuthatches, which are species associated with old-growth forests characterized by tall trees and large diameters, are particularly noteworthy (Maller et al., 2009). Many sources have highlighted the positive impact of both standing dead trees and mature trees on enhancing bird diversity. These trees are crucial not only for animals but also for forest regeneration. Certain birds, like woodpeckers

that nest in tree cavities, prefer tall trees with dead wood and substantial diameters to maximize breeding success and minimize predation risks (Tiberio and Escalante-Pliego, 2006). The survival of five bird species depends on the continuous presence of large trees and shrubs. Dead trees, unlike living ones, serve as foraging sites for birds (Desrochers and Imbeau, 2000). Bird abundance provides valuable insights into the structural complexity of forests. Since the 1960s, studies (e.g., MacArthur and MacArthur, 1961) have shown that bird responses to structural complexity are generally positive. The theory predicts that species richness increases with the diversity of resources associated with the forest canopy structure (MacArthur, 1984).

Subsequent research has consistently demonstrated positive responses to forest structural complexity not only among birds but also across a wide range of forest organisms (e.g., Poulsen, 2002; Roth, 1976; Stein et al., 2014; Tews et al., 2004). Snags and fallen logs are critical indicators of forest biodiversity and essential for conservation planning, despite the need for more long-term studies on how retention forestry practices impact bird populations (Mikusinski et al., 2018). Preserving ecosystem biodiversity and forest structure requires managing human activities such as recreation and minimizing habitat fragmentation. Fragmentation and habitat loss reduce resources and connectivity, exacerbating edge effects that affect species dispersal, colonization, and survival (Fahrig, 2003; Gaston et al., 2003; Warren et al., 2001; Stagol et al., 2007). Different species respond uniquely to habitat changes based on their traits and needs, influencing how fragmentation impacts bird populations (Galetti et al., 2013; Maggini et al., 2014; Bovo et al., 2018; Reino et al., 2018). Fragmentation alters animal behavior by modifying habitat structure, food availability, predation patterns, and microclimatic conditions (Fahrig 2007; Ramos et al., 2020; Hardwick et al., 2015). These changes can disrupt circadian rhythms, foraging behavior, and activity patterns, affecting resource acquisition, energy balance, and vulnerability to predators

(Lehmann et al., 2012; Speakman, 2008; Oliveira Bezerra et al., 2020; Chaves et al., 2011). Roads exacerbate these impacts, with traffic noise affecting wildlife, particularly species attracted to roadsides for hunting, resulting in negative outcomes (Forman et al., 2003; Mason et al., 2016). Bird abundance or density often declines with increasing roadside noise levels (e.g., Reijnen et al., 1996; Silva et al., 2012). Studies have shown a 28% decrease in bird abundance due to noise, accompanied by changes in age structure and reduced body condition (McClure et al., 2013, 2017; Ware et al., 2015). Growing evidence indicates that anthropogenic noise diminishes the quality of visitor experiences in natural areas, partly by masking natural sounds (Dumyahn and Pijanowski 2011; Stack et al., 2011; Rapoza et al., 2015). Conversely, reducing traffic noise levels could potentially improve visitor experiences by reducing the masking of natural sounds (Levenhagen et al., 2020).

Growing outdoor recreational activities in natural settings worsen stress on ecosystems and individual species (Pickering and Hill, 2007; Steven et al., 2011). Conversely, the naturalness, biodiversity, or presence of certain emblematic species can enhance the attractiveness of an area for recreational activities (Knight, 2009; Hammitt et al., 2015; Aasetre et al., 2016). However, recreational activities may conflict with another important function of natural spaces: the preservation of habitats and biodiversity (Green and Giese, 2004; Niemela et al., 2005; Probstl et al., 2010). Recreation is increasingly recognized as a threat to a wide range of species (Ballantyne and Pickering, 2013; BirdLife International, 2015), necessitating careful study of its impact on natural areas and species of conservation concern. The impacts of recreational activities on nature are manifold: trampling affects vascular plants and alters soil conditions, leading to direct destruction of vegetation cover (Cole, 2004; Pickering et al., 2011). Human-induced spread of invasive weeds or pathogens further complicates the issue (Kelly et al., 2003). While some wildlife species adapt to human recreation, there is a growing body of evidence highlighting its negative impacts on

wildlife (Steven et al., 2011; Larson et al., 2016). Recreational activities can even undermine the effectiveness of protected areas (Reed and Merenlender, 2008).

The impact of agriculture on forest bird diversity varies; it may have negative effects on species requiring extensive forest cover, while benefiting generalist birds. Recreation activities often result in habitat loss for ground-cover dependent birds such as Blue Tits and Robins (Steven et al., 2011). In urban settings like Isfahan, park size positively influences bird diversity, whereas overcrowding has a negative effect; circular park shapes are preferred to minimize edge effects on bird populations (Hemami and Zairi, 2011). Sagheb Talebi et al. (2001) observed that in open and degraded forest areas, the canopy opening and subsequent exploitation lead to rapid invasion and growth of herbaceous species such as ferns and raspberry varieties. This invasion is cited as a factor contributing to a slight increase in these areas. The colonization of the forest floor by such species reduces opportunities for other plants, ultimately lowering biodiversity and the density of many bird species, especially umbrella species like woodpeckers. Whitecotton et al. (2000) demonstrated that recreational activities decrease litter depth. In heavily used areas, the average litter depth was 91% lower compared to unused areas. Steven et al. (2011) examined the impact of recreation on bird communities and noted that forest clearance for recreational purposes reduces survival rates for species dependent on bush and shrub cover, such as the blue-throated warbler and red-breasted warbler.

Conclusion

Urbanization and urban development, recreation and agriculture are some of the main factors impacting the abundance and

biodiversity of forest birds living near urban areas. Urbanization has negative effects on the relative abundance and species diversity of all forest birds, as well as the relative abundance of generalist forest birds. These outcomes are attributed to the cumulative effects of various disturbances associated with urbanization, which increase bird mortality and decrease reproductive success. Urbanization has far-reaching effects, including increased construction, roads, air pollution, and higher temperatures, which encroach on habitats and introduce non-native plants. These changes amplify densities of brood parasites and noise levels, while reducing caterpillar abundance. This adversely affects breeding density, hatching success, chick survival, nest productivity, and chick weight, and also increases nest predation rates.

In addition to urbanization, activities such as hiking, road construction, and logging in Alangdareh Recreational Forest Park negatively impact bird populations, leading sensitive species to vacate the area. In contrast, Shastkalateh Protected Forest maintains high bird diversity due to its stable ecosystem, which supports species like European Robins and Winter Wrens with suitable nesting sites and food sources. Conservation strategies should prioritize the preservation of standing dead trees and microhabitats crucial for species such as woodpeckers and Eurasian Nuthatches. Balancing recreational access with wildlife protection can be achieved through thoughtful trail design and adherence to visitor management guidelines.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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