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Does *Argya altirostris* (Hartert, 1909) (Passeriformes: Leiothrichidae) extend its distribution to northern Anatolia?

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Abstract. The Iraq Babbler, *Argya altirostris* (Hartert, 1909), previously known only along the Euphrates and Tigris rivers in Iraq, Syria, and western Iran, was discovered in Türkiye at the end of the 1990s. It was observed only along the Euphrates Valley between Nizip (Gaziantep) and Birecik (Şanlıurfa) for more than 15 years. Recently, it was seen in some other parts of Gaziantep and Şanlıurfa provinces as well as Adıyaman, Hatay, Kahramanmaraş, Mersin, and Osmaniye in south Türkiye. The species was found in a few localities of Adıyaman (Gölbaşı), Hatay (Kırıkhan, Hassa, Samandağ), and Mersin (Silifke) provinces between 2020-2022 in the western and northern direction of its distribution. The six new district records are reported here for the first time. Thus, its distribution has extended to the Mediterranean and the western Türkiye (Anatolia) in the northernmost area of the species' range. Similarly, its distribution in Karbala Province expanded westwards concerning our new locality record from Iraq. To test its expansion in northern and southern Anatolia, we performed species distribution modeling for four time periods, as simulated in five General Circulation Models (GCMs), to evaluate the distributional shifts of the Iraq Babbler over the decades and to forecast its future projections. The results show that the Iraq Babbler could expand its distribution in the Mediterranean and western Türkiye and confirm our field observations. The currently unsuitable areas could become suitable by 2100, most likely expanding its potential habitat in Türkiye.

Keywords: species distribution modeling, climate change, Iraq Babbler, range expansion, range shift, new record, the Middle East.

Introduction

The Iraq Babbler, *Argya altirostris* (Hartert, 1909), is a middle-sized passerine bird native to the reed beds of the Tigris-Euphrates Valley. It occurs from southeastern (Anatolia) Türkiye across central Syria to southeast Iraq along the Euphrates and partly the Tigris basins. It is also distributed in adjacent southwest Iran, in Ahwaz (Birdlife International 2023). The species is typically found in reedbeds, marshes, rural habitats, and forests on the sides of rivers, irrigation canals, adjacent cultivated fields, and thickets (Ticehurst et al. 1922, Al-Dabbagh & Bunni 1981, Stattersfield et al. 1998, BirdLife International 2023). Almost the entire global population of the Iraq Babbler is in the Mesopotamian marshes (Bosley 2006). The destruction of these areas would cause massive extinctions of the species (Bedair et al. 2006). The main threats to the species are the loss of wetlands through large-scale flood mitigation, drainage, and irrigation projects (Maltby 1994), the effects of the Iran-Iraq War (1980-1988), and the increase in urbanization (Stattersfield et al. 1998, IUCN 2018). The reports that the species has not been seen at the Shadegan International Wetland in the last few years are as follows (Kaffashi et al. 2011). Similarly, Maltby (1994) and Stattersfield et al. (1998) noticed the species is likely to decline due to the loss of marsh habitats due to flood control, drainage, irrigation projects, insecticides, and increasing human settlement.

Climate change is one of the major threats to biodiversity in the next century. It has affected the demography, phenology, and distribution of a wide range of plants and animals (e.g., Parmesan et al. 1999, Kullman 2001, Walther et al. 2002, Matthews et al. 2004, Leech & Crick 2007, Wormworth & Şekercioğlu 2011). Species can react by evolutionary adaptation, phenotypic adaptation, phenotypic plasticity, movement, and extinction in a changing climate (Peterson et al. 2001). It has some direct and indirect impacts on birds. The changes in population dynamics, a shift of ranges, migrations and breeding timing, survival rates, the timing of events such as egg-laying, and a peak of food availability during the breeding season have been described by many authors (e.g., Bergmanis & Strazds 1993, Schulz et al. 1998, Böhning-Gaese & Lemoine 2004, Leech & Crick 2007, Wormworht & Şekercioğlu 2011, Gilling et al. 2015). Also, due to some areas becoming favorable and others becoming less, these changes lead to shifts in regional or global patterns of species or local extinctions (Thomas & Lennon 1999, Austin & Rehfisch 2005, Leech & Crick 2007).

Species distribution modeling or habitat suitability models are the most powerful tools for predicting recent and future projections in species distributions (Peterson et al. 2011). It's a class of methods that use occurrence data with environmental data to make a correlative model of the environmental conditions that fulfill a species' ecological requirements and forecast the relative suitability of habitat (Warren & Seifert 2011).

Here, we report six new records for the Iraq Babbler for the first time in southern Anatolia [provinces of Adıyaman (Gölbaşı), Hatay (Kırıkhan, Hassa, Samandağ), and Mersin (Silifke)] and Iraq [provinces of Karbala]. Our fieldwork observation implies it expands its northern distribution border. In general, the northern range limit of a species seems to be influenced more by abiotic factors (e.g., cold temperatures) and the southern range limit of a species by climatological factors (e.g., warming or lack of water in arid regions) and by biotic factors in other humid regions (Böhning-Gaese & Lemoine 2004, Wormworht & Şekercioğlu 2011). Thus, we produced a species distribution model to identify environmental factors affecting the present-time potential distribution of the species and forecast its future projections related to the impacts of climate change. We used

SDM approaches assessing three scenarios of future greenhouse gas emissions (Shared Socioeconomic Pathways, or SSPs) for four time periods, as simulated in 5 general circulation models (GCMs) to assess distributional shifts of the Iraq Babbler addressing decades and project its future distribution. In the study, we presented the results of our fieldwork, projected the present and future distribution using SDM, and made inferences about the range of the species in the future.

Material and methods

Study area

Geologically, Türkiye consists of several continental fragments coalesced into a single late Tertiary landmass. It is divided into the units of the Pontides, the Anatolides-Taurides, and the Arabian Platform (Okay 2008). During the Mesozoic and Tertiary, the Arabian Platform was separated from the Anatolide-Tauride by the southern branch of the NeoTethys, which is now the Assyrian Suture (Şengör & Yılmaz 1981). The southeastern part of Anatolia is the northernmost extension of the Arabian platform (Okay 2008). South Anatolia (Adıyaman, Hatay, and Mersin) is bounded by the Mediterranean Türkiye to the west, East Anatolia to the north, Syria to the south, and Iraq to the southeast. The region has a Mediterranean climate (Köppen: Csa, Beck et al. 2018) with hot, dry summers and mild to cool, wet winters.

Fieldwork

The fieldwork was conducted in the Hatay province (Southern Anatolia) to determine whether the Iraq Babbler expanded its distribution. The species were detected at 35 points in Kırıkhan (near the Karasu River), 1 point in Hassa (Çatılı River), 1 point in Reyhanlı (Amik Dam Lake), and 1 point in Samandağ (Mileyha Wetland, near Asi River) between 8.9.2020 and 22.3.2022. We used the line transect method in different habitats such as meadows, agricultural land, and riverbanks (whose vegetation included a variety of trees, shrubs, and herbs on the banks of the river). A total of 85 transects were surveyed between 1.1.2020 and 21.4.2022. The length of the routes varies between 207 m and 14993 m (average 2716 m, appendix 1). All observations were made in the morning, and individuals were first determined through calls. Bushnell Elite 10x42 binoculars and a Canon 70D camera mounted with a Canon EF 100x400 mm L IS zoom lens were used during the study. Double counting was avoided by allowing for the direction of movements of individuals in flocks. Information like location, behavior, number, and demography of groups was noted.

Occurrence data

A total of 1006 occurrence records were collected from databases (893 from GBIF 2023, 91 from trakus.org, and 6 from dogalhayat.org), available literature sources (7 records, von Diesselhorst 1962, Marchant 1963, Al-Dabbagh 1998, Murdoch & Betton 2008), and during the own fieldwork (9 localities: Adıyaman [Gölbaşı]; Gaziantep [Nizip], Hatay [Hassa, Kırıkhan, and Samandağ]; Mersin [Silifke], Osmaniye and Şanliurfa [Birecik]) for Türkiye and Karbala (Iraq). Overall records were georeferenced using a WGS84 coordinate system and verified for precision with ArcGIS (v10.7, ESRI, California, USA). To reduce sampling bias and ensure a homogeneous sampling effort (Reineking et al. 2013, Boria et al. 2014, Fourcade et al. 2014, Sillero et al. 2021), we randomly subselected one point for each grid cell per 5-km radius buffer around each occurrence record using the spThin ver. 0.2.0 (Aiello-Lammens et al. 2015), rarefying the occurrence records from 1006 to 117 localities. We tested the occurrence records for spatial autocorrelation using Moran's I (Moran 1950), which ranges from -1 (negative autocorrelation) to 0 (no autocorrelation) to +1 (positive autocorrelation) (Sillero et al. 2021). To forecast the future projections of the species in the Middle East, we defined the study area of the reachable area for the species as the entirety of Türkiye and the Arabian Peninsula and clipped it as a polygon between 12.30° N to 42.90° N and 25.30° E to 60.55° E and representing the study area (the accessible area or M area; Soberón & Peterson 2005).

Environmental data

The 19 recent historical bioclimatic layers have been downloaded from WorldClim v2. 1 database (Fick & Hijmans 2017, http://www.worldclim.org/), with 2.5" spatial resolution (~4.7 km). WorldClim variables were derived from monthly temperature and precipitation values as averages from 1970 to 2000. It was detected some visible artifacts in the mean temperature of the wettest quarter (bio8), mean temperature of the driest quarter (bio9), precipitation of the warmest quarter (bio18), and precipitation of the coldest quarter (bio19) (e.g., Escobar et al. 2014, Campbell et al. 2015). We used 15 recent historical bioclimatic variables apart from four variables to find out how to retain odd spatial artifacts that were visually checked (bio8, bio9, bio18, bio19).

To reduce the potential negative impact of multicollinearity and highly intercorrelated (r>0.75 or <-0.75) among the bioclimatic variables (Heikkinen et al. 2006, Dormann et al. 2013), we eliminated the variance inflation factor over 10 and a correlation threshold of 0.75, as suggested by Guisan et al. (2017) using 'usdm' package (Naimi 2016). Six bioclimatic variables were chosen for the predictors: BIO2 = Mean Diurnal Range (Mean of monthly (max temp – min temp)), BIO4 = Temperature Seasonality (standard deviation ×100), BIO10 = Mean Temperature of Warmest Quarter, BIO13 = Precipitation of Wettest Month, BIO14 = Precipitation of Driest Month, BIO15 = Precipitation Seasonality (Coefficient of Variation) concerning the ecological requirements of the species.

The future habitat suitability of the Iraq Babbler was calculated by projecting fitted models to five different global circulation models (GCM), including BCC-CSM2-MR (Wu et al. 2019), CanESM5 (Swart et al. 2019), CNRM-CM6-1 (Voldoire et al. 2019), CNRM-ESM2-1 (Séférian et al. 2019), MIROC6 (Shiogama et al. 2019) some reduction in uncertainty in climate model forecasts (Sanderson et al. 2015). We obtained future climate data from the 6th climate model intercomparison project (CMIP6, https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6) with three shared socioeconomic pathways [SSPs; optimistic – SSP245, middle of the road – SSP370 and worst – SSP585] for the subsequent periods: 2021-2040, 2041-2060, 2061-2080, and 2081-2100.

Species distribution modeling

We built ecological niche models to predict the present-time (recent-historical) and future habitat suitability of the Iraq Babbler across the broad distributional range via the Maxent algorithm (vers 3.4.1) (Phillips et al. 2021). We made the KUENM R package, which let us comprehensive calibrations of SDM (Cobos et al. 2019) to produce a series of candidate models under different combinations of parameter settings in the R v4.0.5 environment.

We performed 1100 candidate models with parameters reflecting all combinations of 22 distinct sets of 6 environmental predictors, 10 regularization multiplier settings (0.1, 0.5, 1, 1.5, 2, 3, 4, 5, 8, 10), and 5 feature class combinations (l, lq, lqp, lqpt, lqpth; linear = l, quadratic = q, product = p, threshold = t, and hinge = h). Model performance was assessed based on the significance (partial ROC, Peterson et al. 2008), with 500 iterations and 50 percent of data for bootstrapping), omission rates (E = ≤5%, Anderson et al. 2003), and model complexity (Akaike information criterion corrected for small sample sizes, AICc ≤2, Warren & Seifert 2011, Radosavljevic & Anderson 2014). We produced final models for the species using the complete set of occurrences and the selected parameterizations.

We performed 15 replicates by cross-validation with clog log outputs of 10,000 background points and transferred these models to the study area for present-time and future scenarios. The final model assessment consisted of partial ROC and omission rate calculations using the independent dataset. The cloglog outputs represent habitat suitability from 0 (unsuitable) to 1 (suitable). We accordingly carried out 60 future projections (5 GCMs × 3 SSPs × 4 time periods) and generated the average for the GCMs scenarios and time intervals with the raster package (Hijmans et al. 2022). We converted them into binary maps of suitable environmental conditions and implemented the 10-percentile training presence logistic threshold approach as recommended by Liu et al. (2005). Results were imported and illustrated with the RasterVis package (Lamigueiro et al. 2022).

Results

The Iraq Babbler, *Argya altirostris* (Hartert, 1909), was seen in four new localities in Türkiye: Adıyaman (Gölbaşı), Hatay (Kırıkhan, Hassa, Samandağ), and Mersin (Silifke) and one locality in Karbala Province in Iraq. Sixty-one records of this species are in Türkiye (Figure 1), and three are in Iraq. Most records are at Hatay (56 locations), one for each at Adıyaman, Mersin, and Osmaniye. Most of its distribution range is a 14.6 km long area at Karasu River between Ilıkpınar and Kamışlar Villages, Kırıkhan. Other locations are situated at a river near Narlıhopur, the meadows near Kodallı Villages, and six individuals were seen at reed beds at Lake Gölbaşı (Balık). Also, one individual was found in the meadowland between Incirli and Yalangoz Villages. A flock with four individuals was seen at Çatılı River, Bintaş, Hassa. The species was recorded in one location in each other provinces (Adıyaman: Gölbaşı, Mersin: Silifke, Osmaniye: Kesmeburun). Some additional information about the species was recorded during the fieldwork. Flocks of seven individuals were recorded twice, with the maximum flock size being observed near the Karasu River. Some juveniles were seen in a flock of six individuals. One pair was seen together. A pair with five juveniles and another flock with some juveniles was observed on the same day.

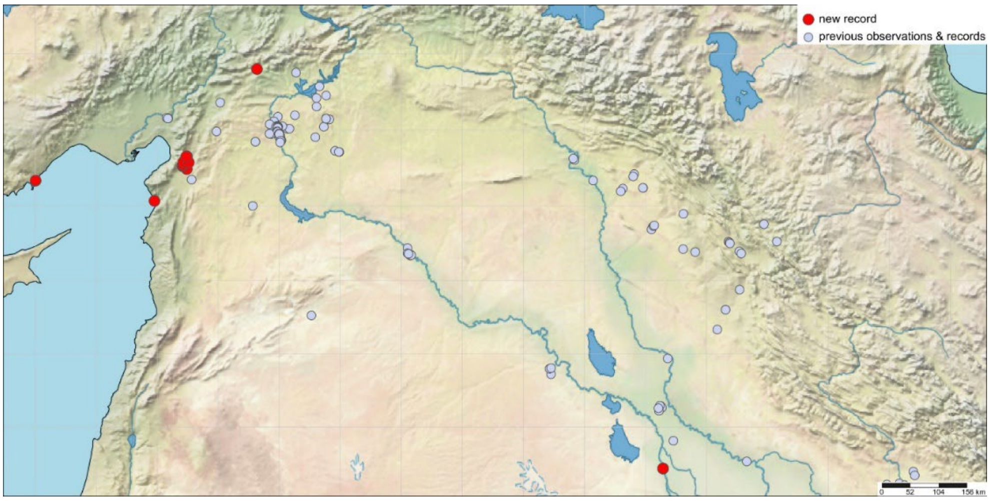

Figure 1. The distribution of *Argya altirostris* (Hartert, 1909) with some new records (red circle) from southern Türkiye and Iraq.

Species distribution modeling

We generated 1100 candidate models by a combination of 22 different sets of 6 environmental predictors. One of the candidate models was the best based on statistical significance (partial ROC < 0.05), good performance (%5 OR = 0.029), and low complexity (AICc= 2610.2) (Appendix 2). The best model included linear, quadratic, product, and threshold features with a regularization parameter of 4 and a high average AUC (AUC= 0.949, SD= 0.022, range = 0.947 – 0.956). The best model has constructed five predictors: Precipitation of Wettest Month (bio13, 40.8%, range = 39.26% - 42.65%), Precipitation Seasonality (bio15, 30.8%, range = 28.65% - 32.75%), Mean Temperature of Warmest Quarter (bio10, 27.6%, range = 26.19% - 29.33%), Mean Diurnal Range (bio2, 0.2%, range = 0.04% - 0.47%) and Precipitation of Driest Month (bio14, 0.6%, range = 0.20% - 0.91%). The most important contribution of environmental variables to the model was the precipitation of the wettest month, precipitation seasonality, and mean temperature of the warmest quarter. Depending on the environmental variables shaping the potential distribution of the species, it is primarily impacted by fluctuations in precipitation.

The current distribution pattern was consistent with the known species distribution (Figure 2). Likely, the distance between the species' natural range, irregular landscapes, or rising mountain ranges to the west will prevent it from expanding into these regions. Apart from its natural range, the Mediterranean Türkiye and Western Anatolia possess habitats partially suitable for the species.

Future projections have predicted that suitable habitats for species will increase in Mediterranean Türkiye and Western Anatolia, particularly in the worst scenarios (SSP585) between 2021 – 2040 (Figure 3). The suitability of these areas enhanced even in the optimistic (SSP245) scenarios of 2081-2100. Especially in the mid of the road (SSP370) and worst projections, unsuitable areas in its present-time distribution in the model will be suitable in 2081-2100 and most likely raise its potential habitats in Türkiye. According to these results, the distribution of the species suggests that it has the potential to expand throughout its range and not just to the northern limit of its distribution. The species may have favorable conditions or ecological opportunities to develop and expand further south or in other directions within its current distribution range.

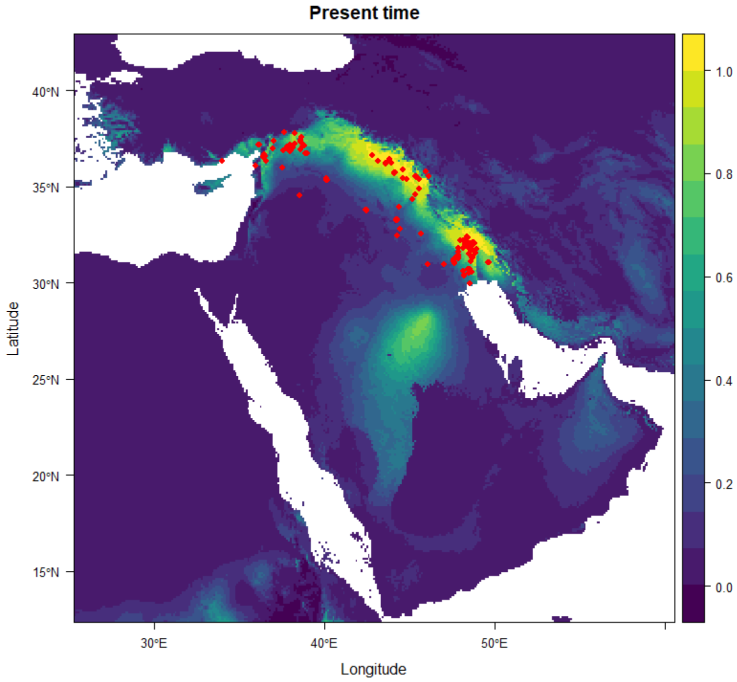

Figure 2. Average predicted climate habitat suitability maps of *A. altirostris* projected to present-time. Red dots denote occurrences. The probability of occurrence varies between 0 (dark violet, low probability) and 1 (yellow, highest probability).

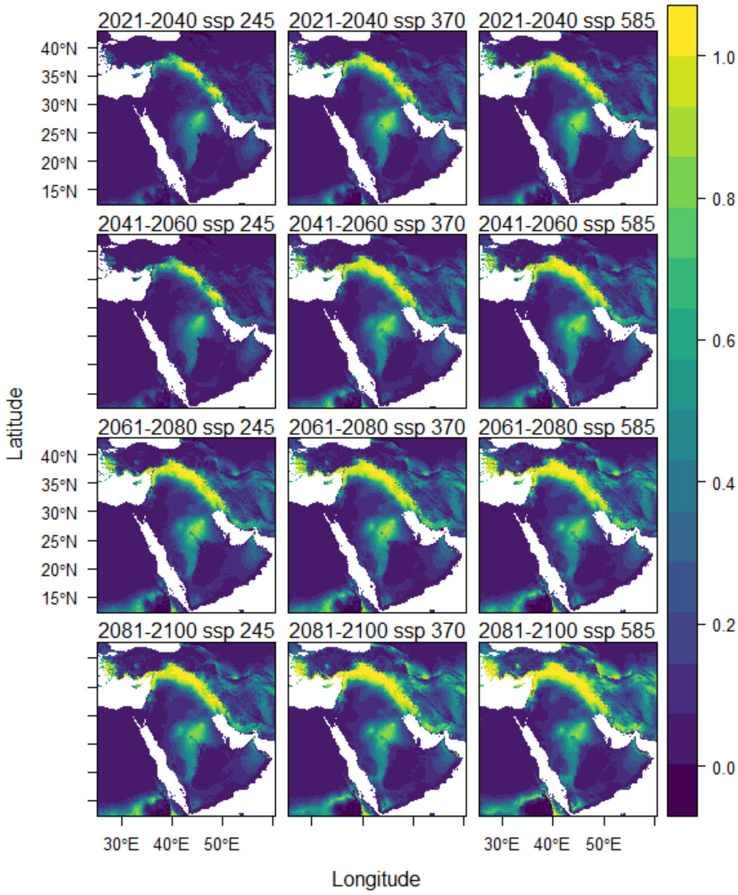

Figure 3. Average predicted climate habitat suitability maps of *A. altirostris* under future climate scenarios for each of four time periods (2021-2040, 2041-2060, 2061-2080, and 2081-2100) and three shared socioeconomic pathways (optimistic - SSP245, middle of the road - SSP370 and worst - SSP585).

Discussion

One of the most important consequences of climate change is the shifting of species ranges in search of physiologically and ecologically favorable conditions. The Iraq Babbler is native to the reed marshes of the Tigris-Euphrates valley. However, there has been a significant loss of wetlands within its range due to large-scale flood control, drainage, and irrigation projects (Maltby 1994), extensive burning, heavy bombing, and use of chemical weapons during the Iran-Iraq war (1980-1988), increasing urbanization and pollution (Stattersfield et al. 1998). As it expands its range due to habitat loss or degradation, it may come into contact with native bird species, potentially leading to competition for resources such as food, nesting sites, and territory. Climate change may also help it better adapt to survive in new habitats. The main reason for range expansion could be the loss or reduction of quality habitat in its range, forcing it to find more resources.

Complex climate changes have brought many changes, such as rising temperatures and increased precipitation, representing dynamic environmental changes for birds (Li et al. 2022). In North America, many bird species have had range expansions during the 20th century (Johnson 1994). In Europe, according to Baumanis & Celmins (1993), similar to the present study, the numbers of Crested Tit (*Lophophanes cristatus*), Blue Tit (*Cyanistes caeruleus*) and Willow Tit (*Poecile montanus*) are becoming more and more optimal in the north and northeast of Latvia (Žalakevičius 1999). Graveland (1998) indicates that several species of migratory marsh birds have declined in Central and West Europe. Lithuanian breeding bird species, which occupy the northern-northeastern-eastern periphery of the common Western Palearctic range and expand their ranges eastward and northeastward, are indicated by Žalakevičius (1999). Bergmanis & Strazds (1993) reported changes in the breeding areas of some woodpecker species in Latvia. While analyzing, they see the ranges moving northward, northeastward, and eastward. The distribution of breeding birds in Britain continued northward, moving 13.5 km for 20 years (Thomas & Lennon 1999, Gilling et al. 2015).

A growing body of data suggests that climate change is a major contributor to changes in bird abundance. Definitively attributing changes in distribution to climate change is very difficult because of the potential influence of many other confounders, such as changes in land use, predator distribution, hunting pressures, and possibly even genetic drift. Thus, while the observations referenced above are indeed suggestive, further research and more time will be required to obtain more convincing evidence of the link between climate change and the range expansions of these species. Thus, while the observations referenced above are indeed suggestive, further research and more time will be required to obtain more convincing evidence of the link between climate change and the range expansions of these species (Crick 2004, Wormworth & Şekercioglu 2011).

Human-induced fires can seriously negatively impact biodiversity and ecosystem functioning (e.g., Flores et al. 2011), as some species are damaged by fire when disturbance frequency limits recovery (Huston 1994). Wildfires are predicted to increase significantly in area and frequency in northern Eurasia (Stocks et al. 1998, Shvidenko & Schepaschenko 2013). Fire dynamics are among the strongest factors influencing the distribution of birds in the Mediterranean (Regos et al. 2015). Both fires and climate can negatively impact bird populations, potentially leading to certain species' decline or favoring others more adaptable to changing conditions. Stubble burning was detected at the site of the first species observed in the province of Hatay (Figure 4). The reedbeds, which are important for the species, suffer from stubble burning, which puts considerable pressure on their populations, as observed throughout the species' range (Stattersfield et al. 1998).

Figure 4. Stubble burning in the species' first observed locality at Hatay, Türkiye (8.9.2020)

Increasing research has shown that birds can respond quickly to climate change (Przybylo et al. 2000, Cresswell & Mccleery 2003). There is strong evidence that species distributions are changing direction in response to climate change and a strong interest in the magnitude of these responses for scientific and conservation purposes (Gillings et al. 2015). As the climate changes into warmer and drier, species' breeding ranges are likely to extend northwards, potentially increasing abundance in some countries, but this ability varies between populations and taxa (Moss 1998, Wilson et al. 2002). Schulz et al. (1998) confirm the number of breeding pairs of White Stork (*Ciconia ciconia*) in the southern periphery of the range (Türkiye, Greece, Bulgaria, and former Yugoslavia) is decreasing.

Over-winter survival rates are likely to decrease under cold, wet conditions in the case of temperate species, as decreasing temperatures increase the rate of heat loss from the body and the effectiveness of the plumage as insulation reduces by wetting of the feathers by rain. Warmer winters may lead to decreased energy costs of thermoregulation. A reduction in snow cover is also likely to increase food availability for many species, including ground feeders such as thrushes. For temperate species, over-winter survival rates are probably to drop under cold, wet conditions as the rate of heat loss from the body increases with diminishing temperatures, and wetting of the feathers by rain reduces the effectiveness of the plumage as insulation. Warmer winters may lead to decreased energy costs of thermoregulation. A reduction in snow cover is also likely to increase food availability for many species, including ground feeders such as thrushes (Leech & Crick 2007).

Changes in disease incidence and interactions with new competitors in the form of invasive and exotic species could also affect the size of future populations (Leech & Crick 2007). It may affect the distribution and demography of pathogens as well as those of bird species themselves. As conditions change, so too may the reproductive rates of pathogens and their vectors and effects include earlier breeding, changes in the timing of migration, changes in breeding performance (egg size, nesting success), changes in population sizes, changes in population distributions; and changes in selection differentials between components of a population (Crick 2004, Faustino et al. 2004).

The effects of global climate change on habitats and food resources are more evident on land and for terrestrial and wetland bird species. It has critical implications for the ecology and biology of birds. The impact is very complex in terms of anthropogenic pressures. Furthermore, not all bird populations are declining; for example, the populations of most southern bird species are increasing (Žalakevičius 1999), such as the Iraq Babbler. In the present study, field surveys were only carried out at the northernmost limit of the species' range, and data on the distribution of the Iraq Babbler in the Euphrates and Tigris valleys, which make up a large part of its distribution, are limited. This may limit the likelihood of the model's predicted results being realized. Collecting data schematically across the species distribution will provide more robust results. To better understand the reasons for the increase in populations of southern bird species, it is crucial to consider the ecological and environmental factors in their habitats, as well as factors such as habitat conversion and climate change.

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