Turkish Journal of Forestry | Türkiye Ormancılık Dergisi
2024, 25(3): 258-266 | Research article (Araştırma makalesi)

Unexpected expansion: Climate change-induced movement of the Cream-colored Courser (*Cursorius cursor*) into Central Anatolia

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Abstract: Climate change is one of the major threats that negatively affects wildlife species and habitats. In recent years, global temperatures have increased, extreme climate events have become more frequent, and many bird species have experienced changes in their geographic ranges, behaviors, and life cycles in response to these environmental changes. The Cream-colored Courser (*Cursorius cursor*), a ground-nesting desert bird from the Glareolidae family, is a bird species that has begun to show changes in its distribution and phenology due to climate change. Normally living in arid environments in the Eastern Palearctic, this species has recently started to be observed in new areas far from its normal range, including Central Anatolia in Türkiye. In recent years, the unexpected appearance and nesting of this species in Tuz Lake, now located in central Türkiye, has raised concerns among conservationists and highlighted the species' vulnerability to climate change. This study aims to model the potential future distribution of the Cream-Coated Courser in Türkiye under two climate change scenarios (SSP 4.5 and SSP 8.5) over three time periods: 2021-2040, 2041-2060 and 2061-2080. Using MaxEnt modeling and climate change projections, the study will identify and interpret the key climatic factors driving these changes in distribution. Our findings will provide critical insights into the future range dynamics of the species and inform conservation strategies to reduce the impacts of climate change on this and other vulnerable bird species.
Keywords: Climate change, Cream-colored courser, Ecological modeling, Anatolia, Ornithology, Türkiye

Beklenmeyen dağılım: İklim değişikliği sonucu Çöl Koşarı'nın (*Cursorius cursor*) Orta Anadolu'ya hareketi

Özet: İklim değişikliği, yaban hayatı türlerini ve habitatlarını olumsuz olarak etkileyen önemli tehditlerden biridir. Özellikle son yıllarda küresel sıcaklıkların artması ve aşırı iklim olayları daha sık yaşanmakta ve birçok kuş türü bu çevresel değişikliklere yanıt olarak coğrafi aralıklarında, davranışlarında ve yaşam döngülerinde değişimler yaşamaktadır. Glareolidae ailesinden, yerde yuvalayan bir çöl kuşu olan Çöl Koşarı (*Cursorius cursor*), iklim değişikliği nedeniyle dağılımında ve fenolojisinde değişiklikler göstermeye başlayan bir kuş türüdür. Normal olarak Doğu Palearktik'teki kurak ortamlarda yaşayan bu tür, son zamanlarda Türkiye'deki Orta Anadolu da dahil olmak üzere, normal aralığından çok uzakta olan yeni bölgelerde gözlemlenmeye başlamıştır. Özellikle bu türün son yıllarda artık Türkiye'nin orta kısmında bulunan Tuz Gölü'nde beklenmedik bir şekilde ortaya çıkması ve yuvalaması korumacılar arasında endişelere yol açmış ve türün iklim değişikliğine karşı savunmasızlığını vurgulamıştır. Bu çalışma, Türkiye'deki Çöl koşarı türünün potansiyel gelecekteki dağılımını iki farklı iklim değişikliği senaryosu (SSP 4.5 ve SSP 8.5) altında 2021-2040, 2041-2060 ve 2061-2080 yıllarını içeren üç zaman periyodu boyunca modellemeyi amaçlamaktadır. Bu çalışmada MaxEnt modellemesi ve iklim değişikliği projeksiyonları kullanılarak, dağılımdaki bu değişimleri yönlendiren temel iklim faktörleri belirlenerek yorumlanmıştır. Çalışma sonucunda elde edilen bulgular, türün gelecekteki coğrafi dağılımı hakkında kritik öngörüler sağlayarak iklim değişikliğinin Çöl koşarı ve diğer savunmasız kuş türleri üzerindeki etkilerinin azaltılması için koruma stratejilerine katkı sağlaması beklenmektedir.
Anahtar kelimeler: İklim değişikliği, Çöl koşarı, Ekolojik modelleme, Anadolu, Ornitoloji, Türkiye

1. Introduction

Climate change has dramatic effect on all wildlife and their habitats and is considered a significant threat to biodiversity on a global scale. Birds are a class that is particularly vulnerable to the negative effects of climate change in this context. Weather patterns are changing, especially due to increasing temperatures and extreme climate events, but birds face difficulties adapting to these rapid environmental changes (Crick, 2004; Pautasso, 2012; Özdemir et al., 2020). One of the most visible indicators of these changes is the distribution, behavior, and phenology of bird species (Evcin, 2023).

Climate change has led to significant shifts in the geographic ranges of bird species, with many moving towards the poles or higher altitudes in search of suitable habitats as global temperatures rise. These shifts are driven by the need to maintain optimal breeding, feeding, and survival conditions as their traditional environments become less hospitable (Thomas and Lennon, 1999; Huntley et al., 2008; Trautmann, 2018; Süel et al., 2022). In Europe, for example, bird species have been observed shifting their ranges northwards at an average rate of 1 km per year, with

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✓ **Received** (Geliş tarihi): 14.08.2024, **Accepted** (Kabul tarihi): 04.09.2024

Citation (Atıf): Evcin, Ö., 2024. Unexpected expansion: Climate change-induced movement of the cream-colored courser (*Cursorius cursor*) into Central Anatolia. Turkish Journal of Forestry, 25(3): 258-266.
DOI: 10.18182/tjf.1533024

some species moving even faster (Diehl, 2019). Alongside these range shifts, climate change also alters the timing of key life cycle events, such as migration and breeding, as rising temperatures affect the availability of crucial resources like food and nesting sites (Cotton, 2003). These changes can lead to mismatches between the timing of food availability and the peak demand of breeding birds, with potential cascading effects on breeding success and population dynamics (Davis et al., 2010).

The combination of range shifts, phenological changes, and habitat loss has contributed to population declines in many bird species. Some species may not be able to adapt quickly enough to the rapidly changing conditions, increasing the risk of local extinctions or even global threats (Žalakevičius, 2001; Jetz et al., 2007). Birds with specialized habitat requirements, limited dispersal abilities, or small population sizes are particularly vulnerable (Travis, 2003; Glushenkov, 2017). Changes in habitats under climate warming influence bird breeding success, breeding ranges, and the effectiveness of bird conservation efforts (Jaffré et al., 2013).

One species where climate change is beginning to alter its distribution and phenology is the Cream-colored Courser (*Cursorius cursor*). The Cream-colored Courser is a species of bird known for its unique cursorial behavior and may face challenges in its foraging and breeding activities due to climate change (Boano et al., 2022).

The Cream-colored Courser is a ground-nesting desert bird belonging to the family Glareolidae. This species is known to inhabit arid environments in the Western Palearctic region (Palomino et al., 2008). Studies have shown that Cream-colored Coursers prefer landscapes with low plant cover (Asensio and Lauenroth, 2012). They have been observed in various regions, including Cape Verde (Rice, 2023), Morocco (Teyar, 2023), North Africa (Traba et al., 2013), and southeast and central Anatolia (Karataş, 2023). The species has also been reported in southern Spain and northern Africa, with confirmed breeding in south Spain (López-Ramírez, 2024). Conservation efforts in places like Cabo Verde have produced positive results for native species like the Cream-colored Courser (Alho et al., 2021). The bird has been noted for its presence in biodiversity-rich areas alongside other endemic bird taxa (Rice, 2023) (Figure 1).

This study aims to determine the potential distribution of the Cream-colored Courser in Türkiye. These species have begun to appear in unexpected locations due to climate change. The fact that the species that is the subject of the study was first seen at Tuz Lake in May 2022, located in the middle of Türkiye, has caused a great resonance in the media and attracted the attention of conservationists (Figure 2).

In this context, the species has reproduced in the region closest to the European continent. The fact that Salt Lake has dried up, especially due to climate change, the spread of this species, which has adapted to the desert habitat in these areas, and the few studies conducted on the species show the importance of the study. The study aims to determine Cream-colored Courser's distribution semi-optimistic and pessimistic scenarios (SSP 4.5 and SSP 8.5) by using climate change projections for 2020-2040, 2040-2060, and 2060-2080. Additionally, the study will identify which climatic factors are driving these shifts in the species' range.

Figure 1. A Photo of Cream-colored Courser (*Cursorius cursor*) (Photo: Commons Wikimedia, 2024)

2. Material and methods

The study area encompasses the entire region of Türkiye. Presence data for the Cream-colored Courser's were obtained from the Global Biodiversity Information Facility (GBIF), specifically from the Birdlife International dataset. The dataset consists of 197 occurrence records submitted to Birdlife until August 2024. To enhance data quality and avoid overfitting, duplicate records and those with coordinate uncertainties exceeding 2 km were removed using the "spThin" package in R (R Core Team, 2021).

For modeling the species' response to climate change, a set of 19 bioclimatic variables with a resolution of 30 arc seconds (~1km) was downloaded from the WorldClim database (v2.1) (Fick and Hijmans, 2017; Kıraç and Mert, 2019). Future climate variables for the periods 2021-2040, 2041-2060 and 2061-2080 were obtained under the Hadley Global Environment Model 2 - Earth System (HadGEM2-ES) based on the Shared Socio-economic Pathways (SSP) 4.5 and 8.5, representing semi-optimistic and pessimistic greenhouse gas emission scenarios.

These bioclimatic variables were clipped to Türkiye's scale using ArcMap and then converted into ASCII format for further analysis. To improve model accuracy, a Pearson correlation test was conducted on the 19 bioclimatic variables using R (R Core Team, 2021). Variables showing a correlation coefficient higher than 0.7 were excluded from the model (Table 1 and Table 2).


SADECE ÇÖL KOŞULLARINDA YAŞAYAN ÇÖL KOŞARI KUŞUNUN TUZ GÖLÜ'NDE GÖRÜLMESİ KAYGILANDIRDI

anka

23.05.2022 11:16

Bağlantıyı Kopyala

KEMAL ONUR ATALAY

Sadece çöl koşullarında yaşamını sürdürebilen 'Çöl Koşar'ı kuşunun Aksaray'da görülmesi kuş gözlemcilerini heyecanlandırdı. Ancak bu kuşun görülmesi, Tuz Gölü'nün sulak alan özelliğinin kaybolduğuna işaret etmesi nedeniyle doğa açısından ise kaygı verici bulundu. Doğa fotoğrafçısı Fahri Tunç, "Biz doğa gözlemcileri ve fotoğrafçıları için çok sevindirici bir gelişme, inanılmaz bir doğa olayını ortaya çıkarmış olduk. Çöl Koşar'ı bize diyor ki 'Artık siz bir çölde yaşıyorsunuz" diye konuştu.

Figure 2. A news article about Cream-colored Courser was observed in Tuz Lake, located in the Middle of Türkiye (Ankahaber, 2022)

Table 1. Bioclimatic variables used for the modeling

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temperature - min temperature)
BIO3 = Isothermality (BIO2/BIO7) (×100)
BIO4 = Temperature Seasonality (standard deviation ×100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

As a result of the correlation analysis, the variables bio1, bio2, bio4, bio8, bio9, bio12, bio15 were selected as the predictors to be included in the model. In the MaxEnt model, bioclimatic variables were treated as continuous data, and response curves and jackknife analyses were generated to evaluate the outcomes. For the output format of the model, the logistic format, which provides results closest to reality, was used, and the regularization multiplier was set to 1 (Baldwin 2009; Phillips et al., 2006; Kıraç, 2021). The model was run with 10 replicates to achieve the best possible result. The success of the modeling outcome is measured using Receiver Operating Characteristic (ROC) curves, as the significance of this curve is assessed by the area under the curve (AUC). The AUC value ranges between 0.5 and 1, with values closer to 1 indicating a more reliable model (Kalleci, 2023). The contribution of environmental variables to the model is assessed using the jackknife analysis (Elith et al., 2011). Finally, the resulting habitat suitability maps were visualized using the ArcMap software.

3. Results

Cream-colored Courser was modeled for the periods 2021-2040, 2041-2060, 2061-2080 (SSP 4.5 and SSP 8.5) and six models were generated. Once the scenario results were interpreted, it became evident that the performance of the habitat suitability model was highly dependable (Phillips et al., 2006), (Figure 3).

The model results identified the following bioclimatic variables as significant: BIO 19 (Precipitation of the Coldest Quarter), BIO 3 (Isothermality), BIO 5 (Maximum Temperature of the Warmest Month), BIO 2 (Mean Diurnal Range), BIO 15 (Precipitation Seasonality). The contributions of these bioclimatic variables to habitat suitability modeling are detailed in Table 3.

According to the Jackknife test results for the Cream-colored Courser habitat suitability model, the variable providing the highest contribution to the model alone is BIO 9 (Precipitation of the Coldest Quarter), followed by BIO 3 (Isothermality), BIO 5 (Maximum Temperature of the

Warmest Month), BIO 2 (Mean Diurnal Range), and BIO 15 (Precipitation Seasonality). The values shown are averages derived from repetitions of the model and demonstrate the contributions each variable would make if used individually in the model (Figure 4).

The habitat suitability map for the *Cursorius cursor* is presented in Figure 5. The map depicts the suitability of the habitat, represented from the lowest suitability (indicated by green) to the highest suitability (represented by red). An analysis of the model map obtained for SSP 4.5 and SSP 8.5 reveals that the *Cursorius cursor* is densely distributed in southeast Anatolia, with a partial spread to the central Anatolian region.

Table 2. Correlation matrix of bioclimate data resulting from correlation analysis

	bio1	bio2	bio3	bio4	bio5	bio6	bio7	bio8	bio9	bio10	bio11	bio12	bio13	bio14	bio15	bio16	bio17	bio18	bio19
bio1	1																		
bio2	0.463	1																	
bio3	0.484	0.673	1																
bio4	0.225	0.610	-0.130	1															
bio5	0.907	0.704	0.438	0.582	1														
bio6	0.916	0.161	0.451	-0.144	0.688	1													
bio7	0.206	0.774	0.089	0.951	0.584	-0.182	1												
bio8	0.398	0.054	0.003	0.078	0.331	0.346	0.062	1											
bio9	0.815	0.509	0.429	0.344	0.827	0.708	0.329	0.113	1										
bio10	0.968	0.560	0.399	0.449	0.973	0.809	0.415	0.379	0.833	1									
bio11	0.956	0.287	0.519	-0.055	0.763	0.984	-0.067	0.374	0.737	0.864	1								
bio12	-0.362	-0.637	-0.378	-0.451	-0.506	-0.132	-0.538	-0.208	-0.423	-0.425	-0.224	1							
bio13	-0.143	-0.521	-0.251	-0.388	-0.297	0.066	-0.476	-0.182	-0.234	-0.207	-0.015	0.861	1						
bio14	-0.478	-0.562	-0.348	-0.458	-0.606	-0.301	-0.485	0.003	-0.612	-0.547	-0.357	0.730	0.366	1					
bio15	0.729	0.515	0.379	0.399	0.764	0.584	0.382	0.075	0.665	0.767	0.638	-0.397	0.017	-0.761	1				
bio16	-0.118	-0.505	-0.252	-0.359	-0.266	0.084	-0.454	-0.182	-0.208	-0.177	0.004	0.869	0.993	0.362	0.034	1			
bio17	-0.483	-0.578	-0.346	-0.482	-0.619	-0.296	-0.507	0.001	-0.613	-0.557	-0.355	0.747	0.383	0.996	-0.769	0.378	1		
bio18	-0.480	-0.575	-0.356	-0.468	-0.617	-0.302	-0.498	0.072	-0.689	-0.551	-0.356	0.717	0.379	0.961	-0.739	0.374	0.964	1	
bio19	0.144	-0.308	0.014	-0.340	-0.020	0.343	-0.411	-0.275	0.147	0.067	0.265	0.724	0.877	0.160	0.206	0.893	0.179	0.121	1

Table 3. Mean variable contributions and permutation importance of models

SSP 2-4.5			SSP 5-8.5		
Variable	Percent contribution (%)	Permutation importance (%)	Variable	Percent contribution (%)	Permutation importance (%)
Bio 2	47.83	3.17	Bio 2	47.07	2.07
Bio 15	21.53	22.53	Bio 15	22.10	27.47
Bio 12	20.17	14.13	Bio 12	19.70	16.30
Bio 9	4.63	33.10	Bio 9	5.20	16.00
Bio 1	4.27	16.03	Bio 1	4.27	28.27
Bio 8	0.97	8.17	Bio 8	1.03	5.73
Bio 4	0.63	2.83	Bio 4	0.63	4.17

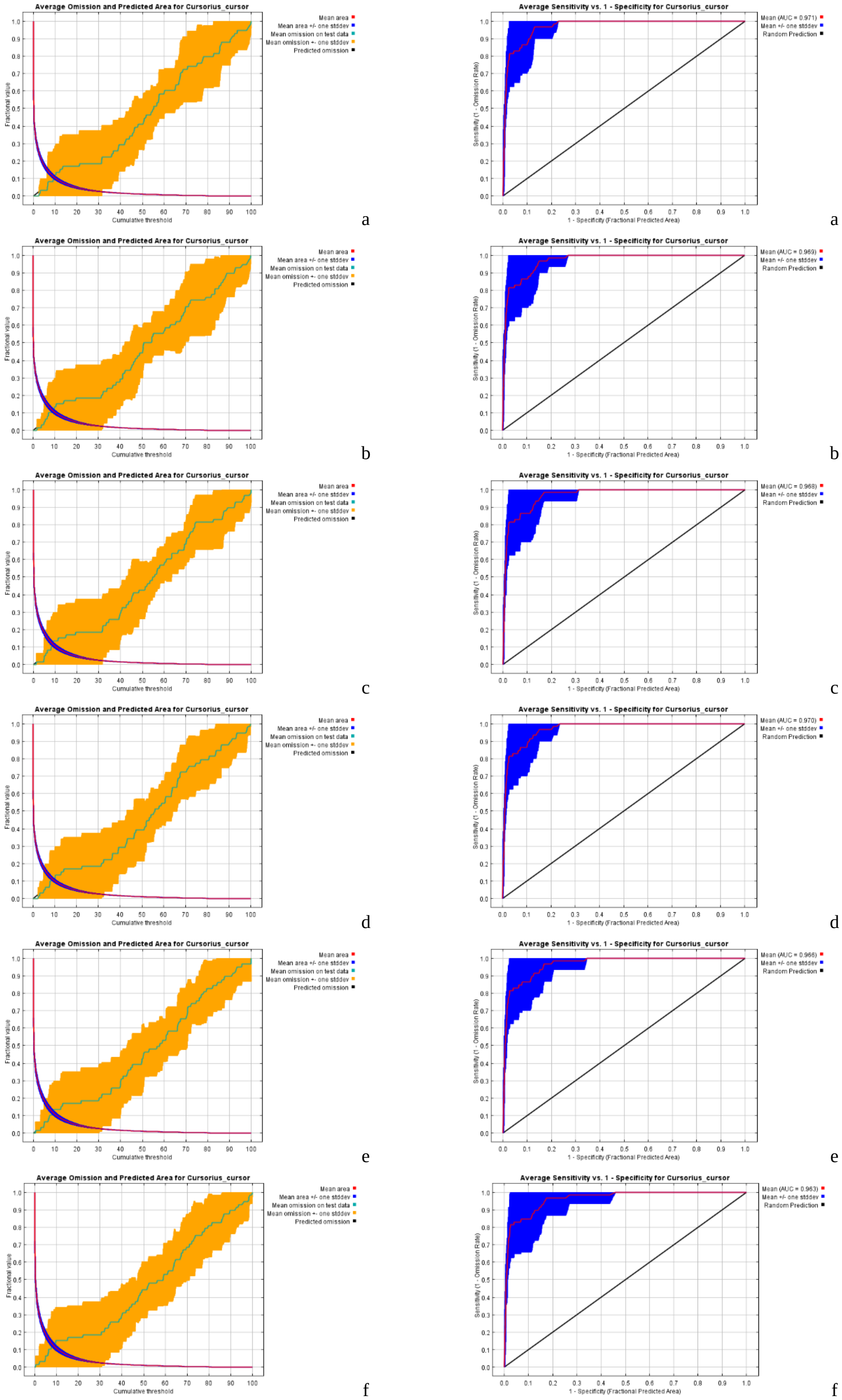
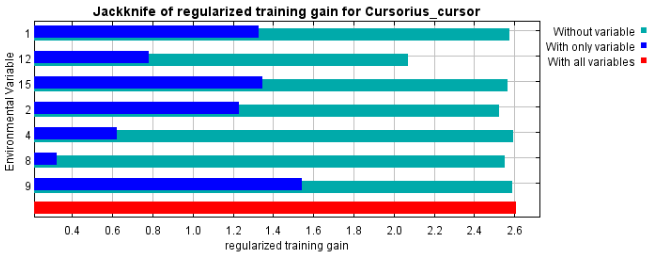
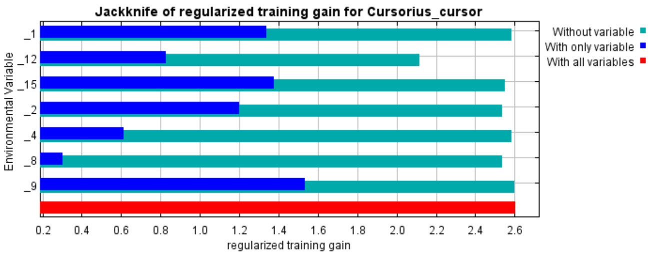


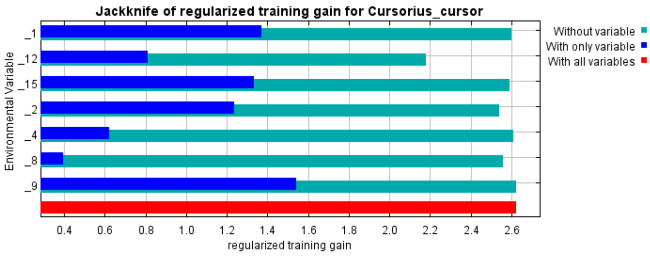
Figure 3. Graphs showing the AUC values and Omission & Predicted Areas a) SSP 2-4.5 2021-2040, b) SSP 2-4.5 2041-2060, c) SSP 2-4.5 2061-2080, d) SSP 5-8.5 2021-2040, e) SSP 5-8.5 2041-2060, f) SSP 5-8.5 2061-2080



SSP 2-4.5 2021-2040



SSP 5-8.5 2021-2040



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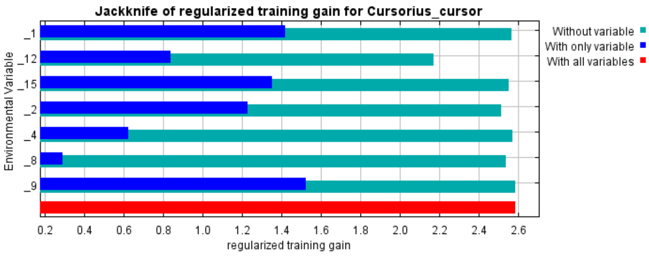

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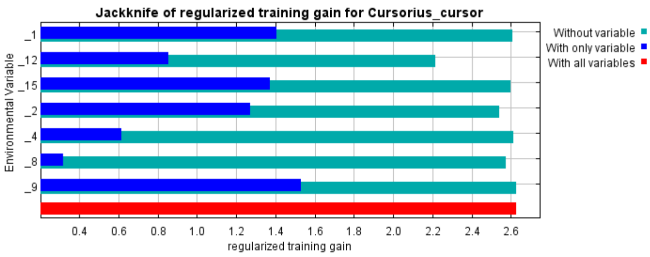
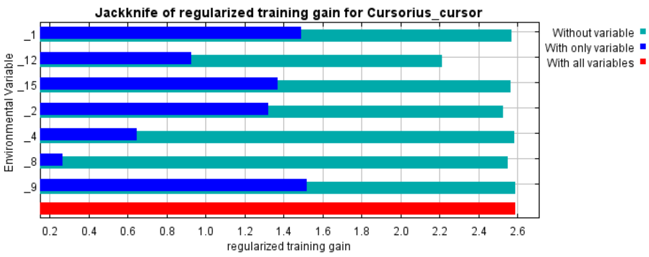
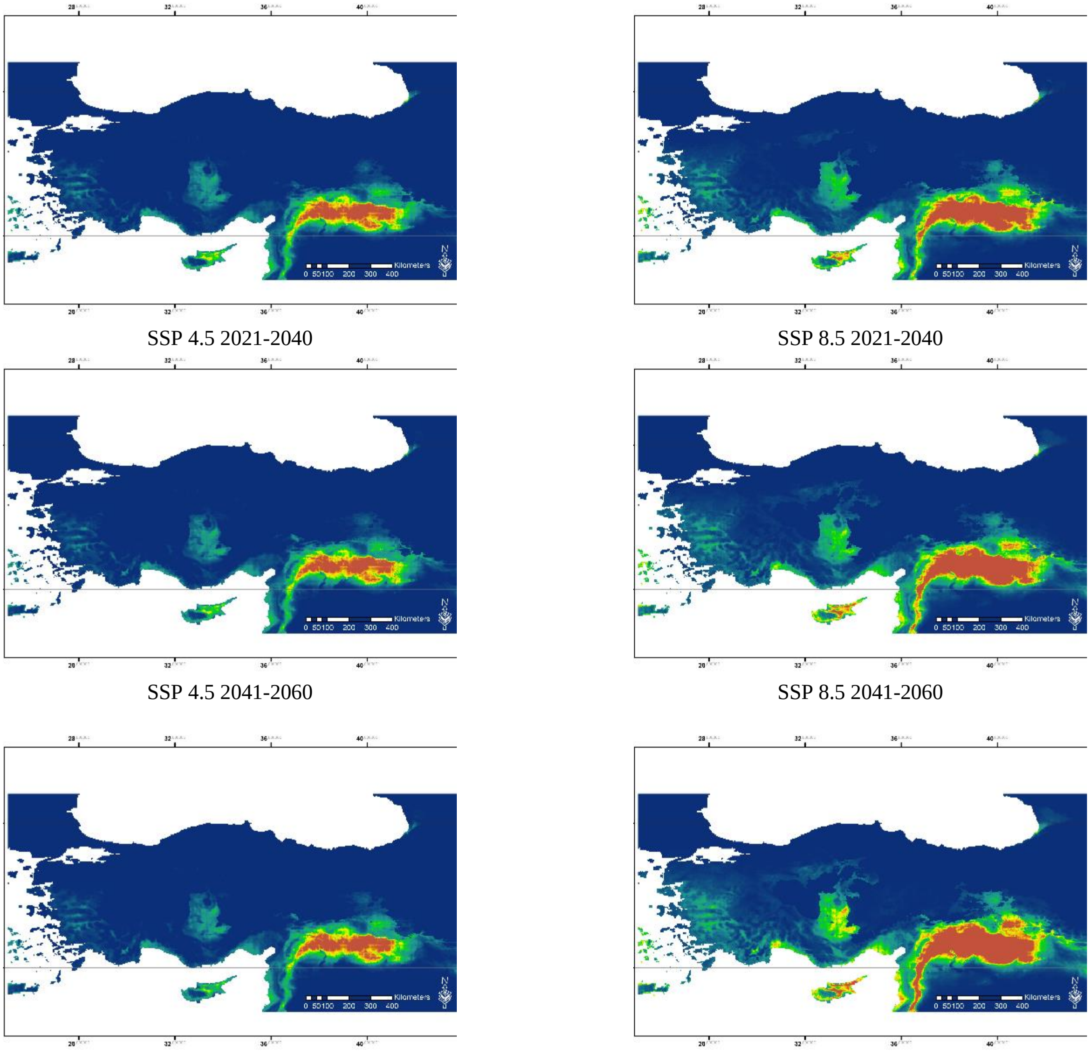


SSP 2-4.5 2061-2080



SSP 5-8.5 2061-2080

Figure 4. Graphs showing jackknife analysis



SSP 4.5 2021-2040 SSP 8.5 2021-2040

SSP 4.5 2041-2060 SSP 8.5 2041-2060

SSP 4.5 2061-2080 SSP 8.5 2061-2080

Figure 5. Potential distribution map of the Cream-colored Courser in Türkiye with Maximum Entropy Approach (MaxEnt)

4. Discussion and conclusion

According to the model results, Bio2 has the highest percent contribution at 48.5%, indicating that the variation between day and night temperatures is crucial in determining the suitability of habitats for the Cream-colored Courser. This suggests that the species may be sensitive to changes in temperature variability, which could be exacerbated under future climate change scenarios. Despite its high contribution, the permutation importance is relatively low (3.6%). This suggests that while Bio2 is important in model construction, other variables may have a stronger influence when the model is subjected to random permutations. This discrepancy could indicate that the species' reliance on the mean diurnal range is more context-dependent, varying across regions or under different climate scenarios. Bio12 contributes 18.4% to the model, highlighting the importance of total annual precipitation in defining the species' distribution. This factor becomes increasingly relevant under climate change scenarios, as precipitation patterns are expected to influence the availability of suitable habitats. The relatively high permutation importance of 21.2% indicates that annual precipitation is a significant predictor in the model and a critical factor in understanding how the Cream-colored Courser may shift its range under future climatic conditions. Under SSP 4.5 and SSP 8.5, changes in precipitation patterns could significantly impact the species' distribution, potentially leading to range contractions or expansions in response to wetter or drier conditions. Bio15 has a percent contribution of 17.5%, reflecting the species' sensitivity to precipitation seasonality. This suggests that the variability in rainfall throughout the year is an important determinant of suitable habitats, particularly in regions where seasonal extremes may become more pronounced under climate change scenarios. However, under future climate scenarios, especially SSP 8.5, where extreme weather events and greater seasonal variability are expected, precipitation seasonality could become more influential in determining the species' future range. Although Bio1 has a lower percent contribution of 5.9%, it has the highest permutation importance (46.9%), indicating that annual mean temperature is a critical factor in defining the Cream-colored Courser's presence. The species' response to temperature changes is likely to be significant under SSP 4.5 and SSP 8.5, with potential shifts in its range depending on how mean temperatures evolve. Under SSP 4.5, where moderate climate change is anticipated, the species may experience shifts in its distribution to areas with more suitable temperatures. Under SSP 8.5, with more severe warming, the species may face greater challenges, possibly leading to range contractions or shifting towards higher altitudes or latitudes where temperatures remain tolerable.

Under SSP 4.5 and SSP 8.5 scenarios, the distribution of the Cream-colored Courser is likely to be influenced by a combination of temperature-related variables (Bio2 and Bio1) and precipitation patterns (Bio12 and Bio15). The species' current adaptation to specific climatic conditions, such as moderate diurnal temperature range and stable precipitation patterns, suggests that climate change could drive significant changes in its range.

When examining the models obtained under the SSP 4.6 semi-optimistic scenario (2021-2040, 2041-2060, 2061-2080), it was found that the current distribution area of the Cream-colored Courser is limited to the southern parts of Türkiye. Analysis of the effects of bioclimatic variables on the species' habitat revealed that with a low increase in temperatures and an increase in the daily temperature range, the species' current distribution in southern Türkiye is largely maintained, with minimal impact on the overall distribution. Similarly, limited changes in precipitation and moderate temperatures during rainy periods help keep the species habitats in the southern regions, resulting in no major changes to its current distribution area.

In contrast, when examining the models obtained under the SSP 8.5 pessimistic scenario (2021-2040, 2041-2060, 2061-2080), it was found that high-temperature increases could lead to the species expanding into areas with higher temperature tolerance and potentially reaching new habitats in the Central Anatolia Region in addition to its current distribution in eastern Türkiye. Increased fluctuations in daily temperature differences and decreases in annual precipitation may lead to the loss of some current distribution areas and potentially create unfavorable conditions, especially in western Türkiye, where elevated temperatures could threaten the species' presence.

A detailed consideration of a population's relationship to its habitat is essential for effectively conserving wild populations. Knowing which habitats are used at higher rates and frequencies allows the identification of the most important biotic and abiotic environmental features. This helps to identify appropriate features to be protected to maintain a suitable conservation status (Cañadas et al., 2005). Habitat loss results in population declines, with smaller populations less likely to be protected over time (Mills, 2012). Doherty et al. (2008) state that it is important to consider the diversity of environmental features in a habitat and the changes in a species preferences due to variable behavioral changes. This may be according to the time of year, food availability, amount of competition, predation risk, and critical life stages. Consideration of these factors is essential in developing conservation management planning. It has been reported in the literature that biotic interactions such as competition or predation or habitat characteristics such as vegetation limit distribution within species at small population scales. At the same time, abiotic factors are the main factors affecting the distribution and abundance of species at large population scales (Newton, 2003).

Studies have shown that climate change can interact with other environmental factors, such as forest fires and vegetation dynamics, further complicating predictions of its impact on bird communities (Regos et al., 2017). Understanding these dynamics is important for developing effective conservation strategies to reduce the effects of climate change on Cream-colored Coursers and other bird species.

Changes in temperature and precipitation patterns can affect the availability of insects and small invertebrates that Cream-colored Courser rely on for food (Pautasso, 2012). In addition, changes in vegetation and habitat structure due to climate change can affect the suitability of nesting sites for Cream-colored Courser, potentially leading to declines in reproductive success (Pautasso, 2012). The ability of the Cream-colored Courser to adapt to these changing environmental conditions will be crucial for its long-term survival in the face of climate change (Regos et al., 2017).

As a result, the *Cursorius cursor*, like many other bird species, is vulnerable to the effects of climate change that can disrupt its feeding, breeding, and general survival. This bird species, which has a distribution in desert climates, has spread to the Salt Lake in the middle of Anatolia clearly shows that Türkiye may also be affected by climate change. In particular, the biggest problems threatening wildlife elements in Türkiye due to climate change and land use change in recent years are the risk of drying out and extinction of wetlands. Unfortunately, with the drying up of wetlands and the loss of habitat suitability, it is likely that species adapted to desert climates, such as the Cream-colored Courser, will spread to unexpected areas.

As a result, minimizing the effects of climate change, understanding the impact of climate change on wildlife and bird species, reducing the threats posed by these environmental changes, and developing conservation strategies to protect biodiversity in the face of ongoing transformations are of significant importance and studies should continue in this context.

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