

Predicting the distribution of the crested tinamous, *Eudromia* spp. (Aves, Tinamiformes)

Fermín Echarri · Claudia Tambussi ·
Carolina Acosta Hospitaleche

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Abstract A bioclimatic analysis of the crested tinamous was conducted to explore climatic factors underpinning the distribution of both *Eudromia elegans* and *E. formosa* and to evaluate its potential application in paleontological studies. The study utilized records throughout the entire known range of *Eudromia* spp. in southern South America. Relationships between 20 environmental parameters and the presence of *Eudromia* species were established, mapping and characterizing their spatial distribution in a geographic information system using BIOCLIM and MAXENT algorithms. The MAXENT prediction map shows a more homogeneous pattern while BIOCLIM showed a patchier pattern. The models applied here generated maps that adjust to the well-known previous distributions of both species. Nevertheless, for *Eudromia elegans*, the distribution predicted by MAXENT includes areas where it is actually considered absent, and the BIOCLIM prediction does not include some areas where it is presumed present. *Eudromia formosa* were found in warmer and wetter sites than *E. elegans*. Low precipitation areas were identified as suitable for *Eudromia elegans*. Strong differences between the climatic profiles for both

Eudromia spp distributions occurred, with the precipitation the most important influence. *E. formosa* tolerates the highest maximum temperatures, whereas *E. elegans* supports the lowest temperatures.

Keywords Southern South America · *Eudromia* spp. · Distribution modeling · Environmental variables analysis

Introduction

The knowledge of species distributions is essential to understand the ecological and evolutionary factors that determine spatial patterns of biodiversity (Graham et al. 2006; Ricklefs 2004). The applications of these data are diverse and abundant in fields such as conservation biology, species management and evolutionary studies. However, the distribution of many bird species of the Neotropics and particularly of Argentina (Porcasi et al. 2005) still remains unknown.

The construction of species distribution models is an alternative approach for the study of species distributions, given the recent advances in satellite collection of data on climatic and ecological variables, GIS technology, and design of numerous algorithms. These models are created from points that represent presence records and predictive variables. The results are projected onto the geographic space to obtain a map of potential distribution of the species, based on the environmental parameters employed (Hay et al. 1996; Pikula et al. 2002). The models generated by this method are much more detailed than the well-known distribution polygons that used to appear in field guides, and have provided the researchers with a pioneering tool to explore diverse issues in ecology, evolution and conservation.

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F. Echarri (✉) · C. Tambussi · C. A. Hospitaleche
División Paleontología Vertebrados, Museo de La Plata,
Paseo del Bosque, s/nro, 1900 La Plata, Argentina
e-mail: fecharri@riera.com.ar

C. Tambussi
e-mail: tambussi@museo.fcnym.unlp.edu.ar

C. A. Hospitaleche
e-mail: acostacaros@museo.fcnym.unlp.edu.ar

For instance, they have been used to study the relationships between environmental parameters and species richness (Araujo et al. 2004; Ferrier et al. 2002; Scotts and Drielsma 2003), invasive potential of non-native species (Goolsby 2004; Peterson 2003), geographical–ecological differentiation of the distribution of related species (Cicero 2004; Graham et al. 2004), and species distributions in past climatic conditions (Tambussi et al. 2005; Tambussi and Acosta Hospitaleche 2002; Hugall et al. 2002; Peterson et al. 2004) or future/projected situations (Araujo et al. 2004; Bakkenes et al. 2002; Skov and Svenning 2004; Thomas et al. 2004; Thuiller et al. 2005).

The distribution and abundance of bird species are known to depend critically on climatic variability at both temporal and spatial scales (Watkinson et al. 2004). Thus, it is possible to analyze climatic and ecological variables in order to diagnose potential distribution areas and determine possible past and future climatic scenarios based on these data. The study of the Tinamidae (Tinamiformes), a taxon that occurs frequently in the paleontological and archaeological record of Argentina, mainly in the Pampean Region (Tambussi 1989a) and in Patagonia (Chiappe 1991; Tambussi and Tonni 1985), represents a particularly interesting case.

The finding of fossil remains of *Eudromia elegans* Geoffroy Saint-Hilaire, 1832, in Late Pliocene layers at Farola Monte Hermoso, Argentina (Tambussi and Acosta Hospitaleche 2001), prompted this distribution analysis which also includes the other recent genus representative, *Eudromia formosa* Lillo, 1895.

Tinamids are emblematic birds within the South American avifauna due to their phylogenetic relationships with the more primitive lineages of Gondwanan birds. Considered as the sister group of Ratitae, the Tinamidae occupy a basal position within the Neornithes, and are the oldest recorded Paleognathae (Cracraft 1988; Cracraft and Mindell 1989; van Tuinen et al. 2000; Braun and Kimball 2002; Mayr and Clarke 2003). The greatest species diversity among recent forms occurs in the central sector of the Neotropical Region (Cabot 1992; Davies 2002), while a few species are distributed in Central America. The 47 recent species are grouped in nine genera, seven of which occur in Argentina and only two (*Tinamotis* Vigors, 1837 and *Eudromia* Geoffroy Saint-Hilaire, 1832) are typically Patagonian (Tambussi 1989b; Tonni and Tambussi 1986). Some species of the family inhabit open areas, others are forest-dwellers, and there are even arboreal species (Cabot 1992). All of them possess limited flight capacity. From an anatomical viewpoint, they vary in the configuration of their pelvis and hindlimb (Tambussi 1989b) and the presence or an absence of a hallux (Echarri 2006).

Miranda-Ribeiro (1938) proposed a general categorization of tinamid species based on their habitat preferences,

proposing the subfamilies Tinaminae for the forest tinamous (forest-dwelling) and Nothurinae for the species from open areas (steppe tinamous). This proposal agrees with the results of Bertelli and Porzecanski (2004) which were based on a combined morphological and molecular analysis. However, the monophyly of the Tinaminae has been supported by neither tegumentary characters (Bertelli et al. 2002) nor skeletal morphology (Bertelli and Chiappe 2002).

In particular, the position of the two species of *Eudromia* within the open areas tinamous (Nothurinae) has been regarded as controversial. They have been considered as either basal within the Nothurinae (Bertelli et al. 2002) or as a derived clade (Porzecanski 2003).

Both recent species of *Eudromia* are medium-sized birds endemic to Argentinian grasslands, where they essentially occur in allopatry (Echarri and Tambussi 2005; Ridgely et al. 2005) with a minimum range overlap (Cabot 1992; Davies 2002; Narosky and Yzurieta 2003).

E. elegans inhabits Andean steppes and mountainsides, occurring from Patagonia to Buenos Aires province in the east, and from central Argentina to southern Salta province in the north. *Eudromia formosa* is distributed from eastern Paraguay to northern Argentina, where it occurs in eastern Salta, western Chaco, western Formosa, eastern Tucumán and northern Santiago del Estero provinces.

Although stated as a possibility by Short (1975), there have been no records of interbreeding, formation of mixed-species pairs or even successful hybridization between the two species of the genera to date, and phylogeny studies based both on morphological and molecular characters (Bertelli et al. 2002; Porzecanski 2003; Bertelli and Porzecanski 2004) have identified *E. elegans* and *E. formosa* as morphologically and phylogenetically separated species.

This paper presents the results of a detailed bioclimatic analysis of the distribution of *E. elegans* and *E. formosa*. The goals of this study were to establish if both species have distinct climatic profiles and to assess the potential application of this information for paleontological studies.

Methods

Species occurrence and environmental data

The data on species presence were extracted from the NatureServe database (Ridgely et al. 2005), complemented with data from Cabot (1992) and Narosky and Yzurieta (2003), and mapped into a geographic information system (DIVA-GIS, Hijmans et al. 2004). In order to extract the presence points, the range maps were superimposed onto a 1-km² grid, and points were assigned to the grids where the species was present. Then, an equal number of points (100)

were selected randomly, and finally used as records of species presence.

The values of the following 19 climatic parameters were extracted from the WORLDCLIM (Hijmans et al. 2005) database: annual mean temperature (AMT), mean diurnal temperature range (MDTR), isothermality (ISOT), temperature seasonality (TS), maximum temperature of warmest period (MTWP), minimum temperature of coldest period (MTCP), temperature annual range (TAR), mean temperature of wettest quarter (MTWQ), mean temperature of driest quarter (MTDQ), mean temperature of warmest quarter (MTHQ), mean temperature of coldest quarter (MTCQ), annual precipitation (AP), precipitation of wettest period (PWP), precipitation of driest period (PDP), precipitation seasonality (PS), precipitation of wettest quarter (PWQ), precipitation of driest quarter (PDQ), precipitation of warmest quarter (PHQ), and precipitation of coldest quarter (PCQ). In addition, the topographic variable altitude (ALT) was included in the analysis. The variables selected include those which describe general trends (i.e., means), as well as the variations in temperature and precipitation, and those that represent potential physiological limits for species.

Modeling methods

An extensive list of modeling techniques and algorithms is available to investigate relationships between the predictor variables and species presence datasets in order to map their spatial distribution (Guisan and Thuiller 2005; Guisan and Zimmermann 2000). Two of these techniques were used here: BIOCLIM (Busby 1991; Nix 1986) and maximum entropy (MAXENT) (Phillips et al. 2006).

The BIOCLIM algorithm generates a climatic envelope in order to identify sites where the climatic values are included in the range defined by the species presence points. Specifically, minimum and maximum values of each climatic variable are identified (climatic profile) in order to define a multidimensional environmental box where the species is probably present. The sites in the study area that show environmental conditions within the limits of this multidimensional box are identified as potential presence sites. The BIOCLIM model was implemented in the software DIVA-GIS.

MAXENT is an application of the machine learning technique called ‘maximum entropy’. This model estimates the likelihood of a species being present by finding the distribution of maximum entropy (i.e., that is closest to uniform) under the constraint that the expected value of each environmental variable under this estimated distribution matches its empirical mean (Phillips et al. 2006).

The climatic profiles obtained from BIOCLIM were used to characterize each species distribution considering the values of AMT, AP, MTWP, MTCP and ALT.

A jackknife procedure was applied in order to analyze the importance of the variables used in the modeling process. This technique is an in-built functionality of MAXENT. Each variable is excluded and a model is reconstructed with the remaining ones. Then, a new model is created using each variable in isolation (Phillips et al. 2006).

Model evaluation

The models generated were assessed both qualitatively and quantitatively. The qualitative evaluation was made by superimposing the maps obtained onto the corresponding distribution ranges (InfoNatura www.natureserve.org/infonatura/—last visited March 2007). For the quantitative evaluation, the original sample of 100 random selected presence points was split and a subset of 25 presence points was set apart to use as a test sample. Then, pseudo-absence points were generated within a size similar to the extension polygon of the species distribution, using the DIVA-GIS software. The predictions were then generated using the remaining 75% of the original presence data (training sample).

To analyze the accuracy of the predictions obtained, Kappa statistics and ROC (receiver operating characteristic) curves were used. The McNemar test was applied to compare performances of the different models. The Kappa statistic assesses the extent to which a model predicts occurrence at a rate higher than expected by chance. The results vary between 1.0 for perfect agreement and 0.0 for random agreement. Since Kappa is asymptotically normally distributed, a basic z -score can be used for significance testing, based on the associated p value (Congalton and Green 1999).

ROC is a threshold-independent technique. The area under the ROC function curve (AUC) is taken as a measure of overall accuracy that is not dependent upon a particular threshold. It measures the probability that, in a pair randomly chosen out of the presence and absence data, the model will assign a higher probability of occurrence to the case with the observed presence (Bonn and Schröder 2001). The values of the AUC vary from 0.5 (no apparent accuracy) to 1.0 (perfect accuracy).

The ROC plotting and AUC calculation transferability test 1.3 software (Schröder 2004) was used to calculate the AUC. A standard bootstrap method was implemented to estimate if the AUC values were significantly different compared to a prediction by chance (e.g., $AUC = 0.5$). The standard error, z statistic, p probability and significant difference from the critical AUC (i.e., 0.5) were estimated.

Since the same training and test samples were used as the input and testing sets, respectively, for all modeling

techniques, the data in the error matrices generated by each model correspond to dependent samples. The McNemar test can cope with dependent test samples and its use has been recommended when comparing the performance of alternative modeling techniques, in this case BIOCLIM and MAXENT (García-Marquez 2006; de Leeuw et al. 2006).

The threshold value at which sensitivity (conditional probability that case x is correctly classified) and specificity (conditional probability that x is mis-classified) are the same was chosen (Bonn and Schröder 2001; Schröder and Richter 1999/2000). This threshold was used as the cut-off level to calculate the Kappa and the McNemar test.

Results

The predicted distributions for both species are shown in Figs. 1a, b and 2a, b. AUC and Kappa values are given in Table 1. The climatic profile of each species is presented in Table 2.

The climatic profiles for the distribution of both *Eudromia* species show marked differences. Precipitations are the most important factor affecting the distributions of *Eudromia* spp.

Eudromia elegans

On visual inspection, the BIOCLIM and MAXENT algorithms produced broadly similar predictions for the potential spatial distribution of *E. elegans* (Fig. 1a, b). The MAXENT prediction map showed a more homogeneous pattern, while BIOCLIM produced a patchier pattern. In view of the known distribution ranges of this species, both predictions are satisfactorily adjusted, even though MAXENT indicated suitable conditions for the species in more extreme southern and northern areas of Argentina, including south of Bolivia, while BIOCLIM predicted areas in central-eastern Argentina (west Santa Fe and north-west Buenos Aires).

AUC and Kappa values were highly significant for all algorithms ($p < 0.0001$) indicating better than random predictions (Table 1). Figure 1c shows the ROC curves for the two algorithms. Even though no significant difference was found between BIOCLIM and MAXENT ($p > 0.05$; McNemar test), the AUC and Kappa values obtained by MAXENT were higher, showing a better performance of the latter application.

The climatic profile obtained using the BIOCLIM model (Table 2) indicates that *E. elegans* is present in areas where the recorded AMT values range between 5 and 21°C. With respect to extreme temperatures, this species tolerates minimum of -5.8°C and maximum of 36°C . Regarding AP, the areas where values vary between 148 and 965 mm

are predicted as suitable, although the average value is 311.45 mm. The average ALT value in the areas where presence of this species is predicted is 538 m, although heights up to 2,300 m are indicated.

The evaluation of the Jackknife procedure allows to conclude that two variables related to precipitation (AP and PWQ) along with TS, have the highest gain when used in isolation, while ISOT is the variable that decreases the gain the most when omitted (Fig. 1d). Average, minimum and maximum values for these variables are shown in Table 2.

Eudromia formosa

BIOCLIM and MAXENT both indicated similar suitable areas that agreed with the known distribution ranges of this species. In addition, the maps generated by the two algorithms also showed that this species could potentially be present in additional northwestern and southern areas (Fig. 2a, b).

Both algorithms generated better than random predictions, with highly statistically significant AUC and Kappa (Table 1) values ($p < 0.0001$). No significant difference was found between the predictive performance of the two models ($p > 0.05$; McNemar test); this can also be seen in the plot of ROC curves (Fig. 2c).

The analysis of the climatic profile for *E. formosa* (Table 2) shows that the areas where this species is present are characterized by a narrow range of AMT values, between 20 and 25°C . With respect to extreme temperatures, *E. formosa* tolerates minimum temperatures of 5°C and maximum of 36°C . The species inhabit areas with AP values between 494 and 914 mm. Although heights of up to 490 m are recorded in the areas where this species is present, the average ALT value is 195 m.

According to the results of the jackknife procedure, three variables, all of them linked to precipitation, show the highest gains when analyzed individually: AP, PWQ and PWP. ALT is the variable that decreases gain the most when omitted (Fig. 2d). Average, minimum and maximum values for these variables are shown in Table 2.

Discussion

Osteologically, the earliest recorded fossil tinamids (early middle Miocene, Santacrucian age from Argentina) resemble recent species. Moreover, fossil tinamids are sometimes indistinguishable from living representatives (Tambussi and Noriega 1996).

An indeterminate species of *Eudromia* from La Pampa, Argentina (late Miocene, Huayquerian age) (Tambussi 1989) is the first record of the genus. As far as is known, *E. olsoni* Tambussi and Tonni 1985 is the only paleospecies

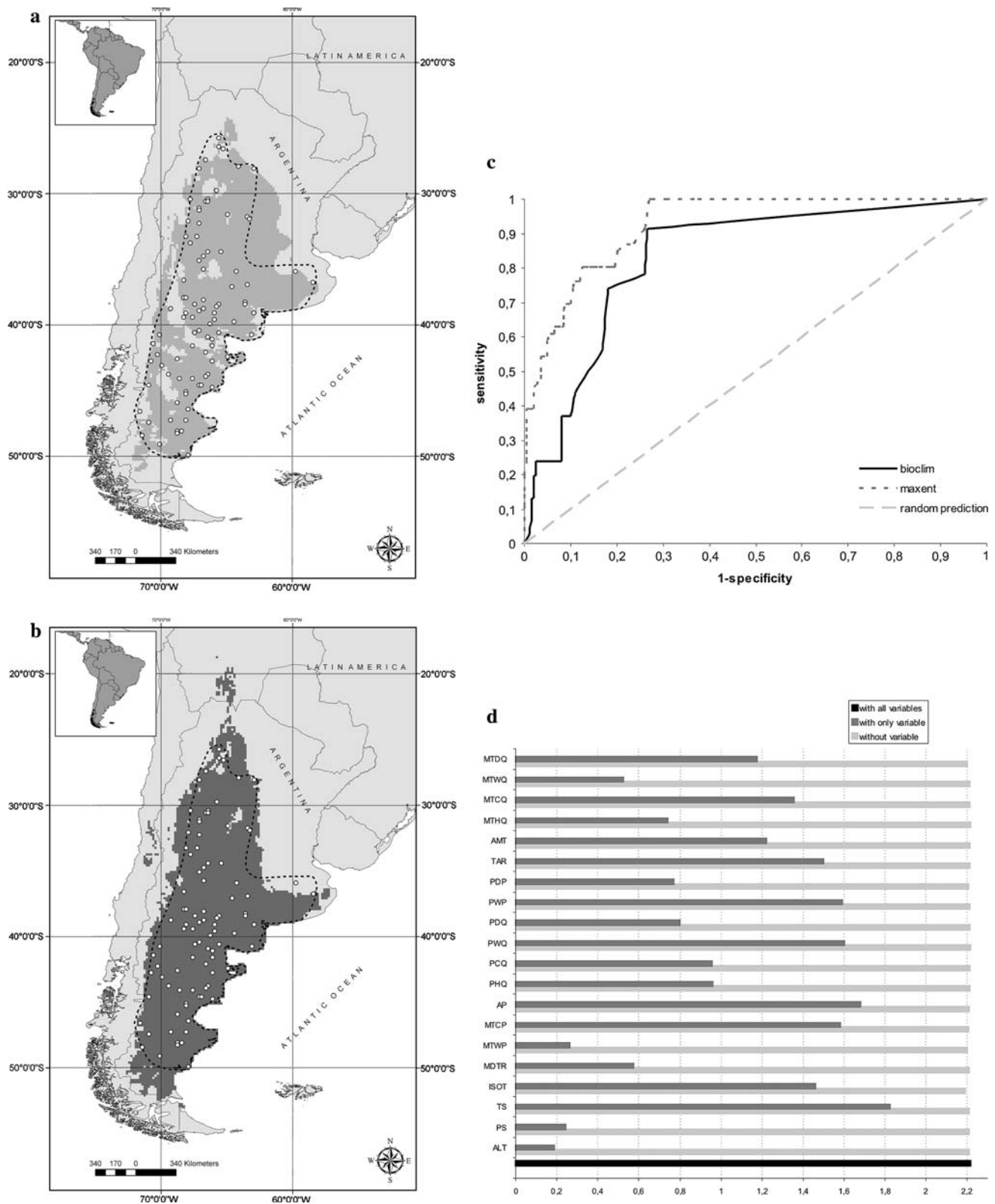


Fig. 1 *Eudromia elegans*. Predicted potential distribution using **a** BIOCLIM and **b** MAXENT, showing the location of occurrence points and the known distribution ranges. **c** Receiver operating characteristic (ROC) curves for both algorithms. **d** Jackknife of training gain

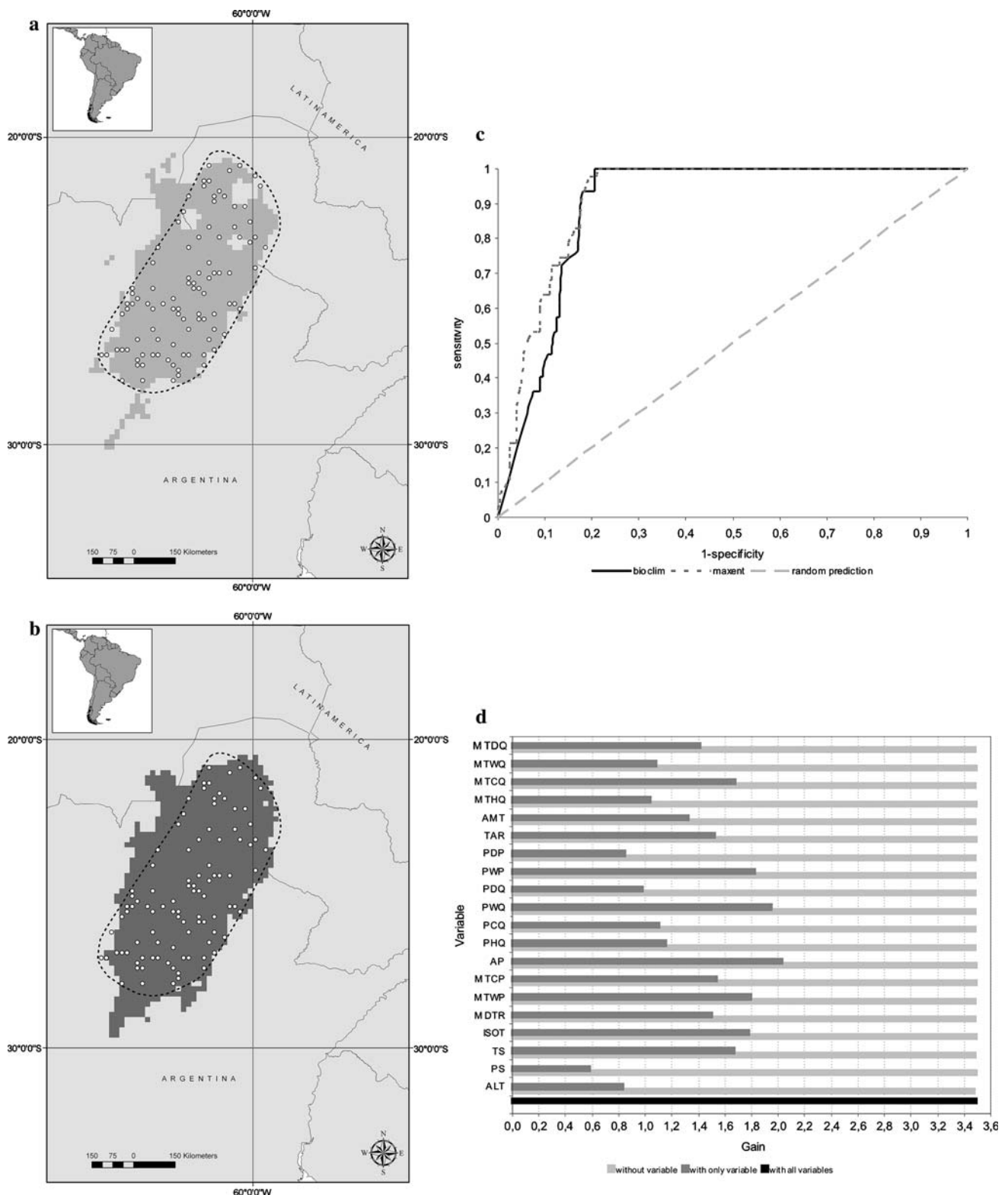


Fig. 2 *Eudromia formosa*. Predicted potential distribution using **a** BIOCLIM and **b** MAXENT, showing the location of occurrence points and the known distribution ranges. **c** Receiver operating characteristic (ROC) curves for both algorithms. **d** Jackknife of training gain

of the genus, recorded in the Early Middle Pliocene (Montehermosan age) of Buenos Aires Province (Argentina).

Several fossil materials from the late Cenozoic can be reliably assigned to *E. elegans*. The earliest record, corresponding to the early Pliocene of the Farola Monte

Table 1 Results of receiver operating characteristic (ROC) and Kappa statistic analyses for both species

		AUC	SE	Lower	Upper	<i>z</i>	<i>p</i>	Kappa	SE	Lower	Upper	<i>z</i>	<i>p</i>
<i>Eudromia elegans</i>	BIOCLIM	0.83	0.0303	0.77	0.89	10.9	<0.0001	0.39	0.0595	0.27	0.50	6.7	<0.0001
	MAXENT	0.93	0.0175	0.89	0.96	24.3	<0.0001	0.49	0.0612	0.37	0.61	8.1	<0.0001
<i>Eudromia formosa</i>	BIOCLIM	0.89	0.0193	0.86	0.93	20.4	<0.0001	0.50	0.0628	0.38	0.63	8.2	<0.0001
	MAXENT	0.91	0.0180	0.88	0.95	23.1	<0.0001	0.54	0.0601	0.43	0.66	8.9	<0.0001

The area under the curve (AUC) and the Kappa statistic is given for BIOCLIM and MAXENT

Table 2 Climatic profiles for both species

	<i>Eudromia elegans</i>							<i>Eudromia formosa</i>						
	Media	SD	Min	2.50	97.50	Max		Media	SD	Min	2.50	97.50	Max	
Annual mean temperature	13.53	3.55	4.93	7.12	20.35	21.19		22.47	1.19	20.02	20.38	25.06	25.18	
Mean diurnal range	13.75	1.95	9.23	10.41	16.78	17.37		13.85	0.59	12.72	12.96	14.89	14.95	
Isothermality	48.63	2.05	44.61	44.95	51.90	55.26		53.34	2.28	47.95	48.81	57.88	58.75	
Temperature seasonality	546.96	55.17	400.63	431.86	617.51	637.29		432.90	46.18	331.93	339.34	504.93	519.35	
Max temperature of warmest period	28.45	4.61	16.40	19.27	34.65	36.40		34.96	0.74	31.70	33.02	36.10	36.30	
Min temperature of coldest period	0.23	2.34	−5.80	−4.24	5.25	6.50		8.91	2.03	5.00	5.72	13.22	13.70	
Temperature annual range	28.22	3.42	20.70	22.28	32.97	33.50		26.05	1.96	21.80	22.34	29.36	30.10	
Mean temperature of wettest quarter	14.65	8.06	1.43	1.69	26.65	27.18		26.84	0.81	24.77	25.14	28.68	29.08	
Mean temperature of driest quarter	11.20	3.51	5.83	6.46	19.48	21.00		17.18	1.99	13.63	14.19	21.56	22.20	
Mean temperature of warmest quarter	20.16	3.90	10.35	13.19	26.83	27.30		27.43	0.62	24.93	25.99	28.77	29.08	
Mean temperature of coldest quarter	6.78	3.27	−0.90	0.91	13.49	14.87		16.91	1.70	13.63	13.92	20.37	20.67	
Annual precipitation	311.45	177.97	148.00	151.10	798.90	965.00		678.16	85.77	494.00	551.60	890.20	914.00	
Precipitation of wettest period	47.82	30.14	17.00	19.28	123.25	159.00		116.95	14.07	88.00	91.80	142.40	162.00	
Precipitation of driest period	10.17	6.91	0.00	2.00	18.00	50.00		7.29	4.24	1.00	1.00	17.00	20.00	
Precipitation seasonality	47.32	26.46	18.38	18.71	106.84	123.49		74.49	11.58	48.43	53.61	93.46	97.75	
Precipitation of wettest quarter	126.73	82.16	44.00	49.55	334.58	411.00		318.53	34.50	251.00	264.40	394.60	438.00	
Precipitation of driest quarter	36.02	22.18	2.00	10.00	73.60	153.00		31.35	14.52	11.00	12.00	58.80	83.00	
Precipitation of warmest quarter	105.40	90.77	21.00	24.00	327.75	411.00		311.62	37.26	221.00	247.60	389.20	429.00	
Precipitation of coldest quarter	50.17	32.71	3.00	10.00	141.25	191.00		43.79	24.90	11.00	12.00	87.80	114.00	
Altitude	537.68	454.89	24.00	41.10	1,849.58	2,311.00		194.58	71.21	108.00	116.80	365.20	490.00	

Hermoso locality, Buenos Aires Province, Argentina, consists of a complete sternum (MD 01-02) deposited in the Museo de Ciencias Naturales “Carlos Darwin” at Punta Alta (Tambussi and Acosta Hospitaleche 2001). Up to the present, the avifauna recorded at this locality has been interpreted as indicative of open and xeric environments, with warm temperate to cold temperate climatic conditions (Tambussi 1995; Tambussi and Noriega 1996). The results of the present work allow us to refine these data and provide a more accurate scenario.

Additional materials assigned to *E. elegans* were recovered from Las Cuevas Creek (Santa Cruz Province) from levels of the Late Pleistocene–Holocene and several Holocene archaeological sites of Pampean Region and northern Patagonia (Tambussi and Tonni 1985). As far as we know, fossils of *E. formosa* were not recorded. There are no records of *E. elegans* further north than Entre Ríos

Province (Holocene) and further south than southern Buenos Aires province (Pleistocene).

As previously mentioned, due to the fact that climatic constraints affect bird physiology, climate is the major—but not exclusive—abiotic factor in the determination of the geographical range of avian species both at macro-ecological and global scales. This assumption implies that the occurrence of a species may be expected if the characteristics of climate fall within the species’ tolerance range, although some authors have noted that the species occupy only a portion of their potential niche space (Soberón and Peterson 2005).

As stated before, we consider that the two species studied here are essentially allopatric. But since birds often change their distributions quickly, there might be very limited regions where their mapped ranges approach one another, and therefore the possibility of *E. elegans* and

E. formosa occurring together. In these regions of overlap, there could be other factors in addition to the ones analyzed in this work that determine their range limits, like the presence of the competing representative species; but both those limited overlapping zones and the ecological relations between these two tinamous are poorly known and should be studied in depth.

In previous modeling studies, the relationships between climatic parameters and *Eudromia* species were restricted to coarse spatial resolutions and/or climate variables (i.e., January isotherm vs July isotherm or annual precipitation) (Tambussi and Acosta Hospitaleche 2001), whereas this work is an attempt to refine the spatial resolution to $\sim 1 \text{ km}^2$.

In general, the MAXENT algorithm showed a better performance, obtaining higher values of Kappa and AUC. Despite both algorithms generating maps satisfactorily adjusted to the previously known distribution of the species, it is noteworthy that in the case of *E. elegans* the predicted distribution includes areas where it is actually considered absent but, conversely, omits those where the species is presumed present. This should be taken into account to modify and improve the accuracy of the distribution of this species in current field guides.

E. formosa is more tolerant than *E. elegans* to MTWP (36.10°C). At the other end of the temperature range, *E. elegans* tolerates the lowest values (−4.24°C) of the variable MTCP. This is clearly reflected in the respective ATM values, with a mean of 22.47°C for *E. formosa* and 13.53°C for *E. elegans*. Precipitation-related variables were identified as highly influential in the distribution of both *Eudromia* species, according to the jackknife procedure implemented in MAXENT (Figs. 1d, 2d).

E. formosa occurs in areas with annual precipitation, ranging between 494 and 914 mm (mean 678.16), while *E. elegans* is present in zones where these values range between 148 and 965 mm, with a mean of 311.45 mm. The Patagonian climatic region (sensu García 1990, 1992, 1994) is characterized by mean annual precipitations of up to 300 mm, in agreement with the typification of a xeric environment. However, the distribution range of *E. elegans* includes regions where annual precipitation exceeds 900 mm. Consequently, the use of this species as an indicator of xeric environments should be approached with caution.

Even though the distribution modeling methods described in this work have been already applied to birds (Peterson 2001), the present study is a pioneer application to South American species. In future, such calculations may be crucial for comparing shifts in species' ranges under the effects of climate change due to global warming.

Zusammenfassung

Vorhersage der Verbreitung von Perlsteihhnern
Eudromia spp. (Aves, Tinamiformes)

Eine bioklimatische Analyse von Perlsteihhnern wurde durchgefhrt, um klimatische Faktoren zu untersuchen, welche die Verteilung von *E. elegans* und *E. formosa* untermauern, und die mgliche Anwendung dieser Analyse in palontologischen Studien zu bewerten. Die Studie nutzte Aufzeichnungen aus dem gesamten bekannten Verbreitungsgebiet von *Eudromia* spp. im sdlichen Sdamerika. Beziehungen zwischen zwanzig Umweltparametern und dem Vorkommen von *Eudromia*-Arten wurden ermittelt, indem ihre rumliche Verbreitung in einem geographischen Informationssystem unter Verwendung von BIOCLIM und MAXENT-Algorithmen kartiert und charakterisiert wurde. Die von MAXENT vorhergesagte Karte zeigt ein homogeneres Muster, whrend BIOCLIM ein fleckenhafteres Muster erkennen lsst. Die hier angewendeten Modelle erzeugten Karten, die sich an die bekannten bisherigen Verteilungen beider Arten anpassen. Dennoch schliet die von MAXENT vorhergesagte Verteilung von *E. elegans* Regionen ein, wo diese Art in der Tat als fehlend angesehen wird, und die BIOCLIM-Vorhersage schliet einige Regionen nicht mit ein, in denen die Art vermutlich vorkommt. *E. formosa* wurde an wrmeren und feuchteren Standorten als *E. elegans* gefunden. Regionen mit geringen Niederschlgen wurden als fr *E. elegans* geeignet identifiziert. Starke Unterschiede zwischen den klimatischen Profilen fr die beiden Verbreitungen von *Eudromia* spp. traten in Erscheinung, mit den Niederschlgen als dem strksten Einflussfaktor. *E. formosa* toleriert die hchsten Maximaltemperaturen, wohingegen *E. elegans* die niedrigsten Temperaturen aushlt.

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