The geographic and seasonal potential distribution of the little known Fuertes's Oriole *Icterus fuertesi*

ARIADNA TOBÓN-SAMPEDRO and OCTAVIO R. ROJAS-SOTO

Summary

Endemic species and those with restricted distribution ranges are a priority and national responsibility for global conservation. Fuertes's Oriole *Icterus fuertesi* is a Mexican endemic species and is perhaps one of the least known birds in the country. It has traditionally been regarded as conspecific with the Orchard Oriole *I. spurius*, but recently it has been suggested that it is a distinct species, causing concern about its risk status. There is a scarcity of information related to the geographic and seasonal distribution of Fuertes's Oriole, as well as a lack of information regarding its abundance and habitat preferences. We gathered all the available records, and used ecological niche modelling to analyse the spatial and temporal patterns of the distribution of the species. We also carried out field surveys in the surroundings of known locations of the species in order to determine its abundance. We found that the species is narrowly and locally restricted to the surroundings of eight localities along the Gulf coast of Mexico that constitute small and discontinuous areas of presence. We also found no evidence of migration to the Pacific Coast in winter, as has been historically thought. Instead, our results suggest that the species exhibits a short-distance migration, with northern populations migrating to the southern range along the Gulf coast of Mexico. Analysis of abundance and field observations confirm that the species is restricted to highly modified wetland landscapes associated with urban and semi-urban habitats. Based on these results, we suggest the urgent reassignment of its risk category.

Resumen

Las especies endémicas y aquellas con intervalos de distribución restringidos son una prioridad y responsabilidad nacional para la conservación global. La calandria de Fuertes *Icterus fuertesi* es una forma endémica de México y es quizá de las aves menos conocidas. Tradicionalmente ha sido considerada como con-específica de *I. spurius*, aunque recientemente se ha sugerido que es una especie distinta, lo que conlleva a una preocupación acerca de su estatus de riesgo. Existe escasa información relacionada con la distribución geográfica y estacional de la calandria de Fuertes, así como poca información sobre su abundancia. Se recopilaron todos los registros disponibles de la especie y, vía modelado de nicho ecológico (ENM) fueron analizados los patrones de distribución espacial y temporal. Se realizó trabajo de campo para estimar la abundancia. Se encontró que la especie está localmente restringida a los alrededores de ocho localidades a lo largo de la costa del Golfo de México, lo que constituye pequeñas y discontinuas áreas de presencia. No se encontraron evidencias de la migración a la costa del Pacífico durante el invierno, como históricamente ha sido sugerido, en vez de ello, los resultados sugieren que la especie presenta una migración de corta distancia, donde las poblaciones del norte migran hacia el sur de su intervalo de distribución dentro de la costa del Golfo de México. Los análisis de abundancia y observaciones en campo confirman que la especie se encuentra restringida a humedales altamente modificados y asociada a hábitats

urbanos y semi-urbanos. Basados en estos resultados se sugiere una urgente necesidad de evaluar su categoría de riesgo.

Introduction

There have been many efforts to identify endangered species worldwide, as well as the causes of the threats and population trends (ICBP 1992, BirdLife International 2000, UNEP-WCMC 2011, IUCN 2012). In fact, it has been suggested that species with a restricted distribution range (e.g. those with a distribution range of less than 20,000 km² that are classified as 'Vulnerable' following the IUCN criteria) represent a global conservation priority (Stattersfield *et al.* 1998, IUCN 2012). Narrowly endemic species are a particularly high priority for conservation at national level, given that they are part of the national biological heritage and a responsibility for global conservation (Arizmendi 2003, González-García and Gomez de Silva 2003). Unfortunately, there are still many examples of groups that have remained at the margin of legal protection and conservation efforts due to a lack of knowledge concerning taxonomy, distribution (geographical and seasonal) and/or life cycle (Rojas-Soto *et al.* 2010).

Fuertes's Oriole *Icterus fuertesi* is endemic to Mexico and is perhaps the least known bird in the country. It has traditionally been regarded as a subspecies of Orchard Oriole *I. spurius* (Blake 1953, AOU 1983, 1998) due to its morphological similarity in all respects, apart from the replacement of the chestnut plumage by ochre (Jaramillo and Burke 1999). However, its evolutionary independence has recently been recognised (Baker *et al.* 2003, Navarro-Sigüenza and Peterson 2004, Kiere *et al.* 2007, Clements *et al.* 2012, Gill and Donsker 2012). This has emerged as a result of various types of evidence, such as the analysis of mitochondrial DNA (Baker *et al.* 2003), plumage colouration (Omland and Layon 2000, Kiere *et al.* 2007), differences in size (Chapman 1911, Graber and Graber 1954), their migratory patterns (Jaramillo and Burke 1999), and also their distribution during the breeding season (Martin and Omland 2011), suggesting specific recognition of these two lineages, as suggested by Chapman (1911).

Acceptance of Fuertes's Oriole as an independent species (Navarro-Sigüenza and Peterson 2004, Clements *et al.* 2012, Gill and Donsker 2012) creates concern about its risk status since it implies that, as a lineage, it has restricted geographical distribution and may therefore have been assigned an inadequate risk category under both national and international legislation (Rojas-Soto *et al.* 2010). Currently, Fuertes's Oriole is a subspecies categorised as "Subject to Special Protection" under Mexican legislation (NOM-059-SEMARNAT-2010; SEMARNAT 2010) and has not yet been assessed by IUCN (2012).

The known distribution of Fuertes's Oriole in the breeding season (March to August) includes a small number of occurrence records, all of which are concentrated in eight localities distributed discontinuously along the coast of the Gulf of Mexico from southern Tamaulipas to southern Veracruz, Mexico (Chapman 1911, Graber and Graber 1954, Howell and Webb 1995, Jaramillo and Burke 1999, Kiere *et al.* 2007, Martin and Omland 2011; Figure 1), although there have been occasional sightings in Brownsville (Dickerman 1964) and Harlingen (Hess 2004) in Southern Texas. Despite limited information concerning the winter range of this species (primarily based on few immature specimens in collections and a single photograph), it has traditionally been thought that Fuerte's Oriole makes a short migration to the Pacific coastal plain, in the states of Guerrero, Oaxaca and Chiapas, Mexico (Blake 1953, AOU 1983, 1998, Howell and Webb 1995).

The use of ecological niche modelling (ENM) facilitates analysis of the geographical, ecological and seasonal distribution of a species, and has thus been used for different purposes in conservation, such as the design and planning of reserves (e.g. Ortega-Huerta and Peterson 2004, Wilson *et al.* 2005), evaluation of the response of species to climate change (e.g. Peterson *et al.* 2001, Marini *et al.* 2009), exploration of the impact of invasive species on indigenous species (e.g. Rodríguez *et al.* 2007, Martínez-Morales *et al.* 2010, Jiménez-Valverde *et al.* 2011) and prioritisation of areas for reintroduction (e.g. Martínez-Meyer *et al.* 2006), among others. However, ENM is also an
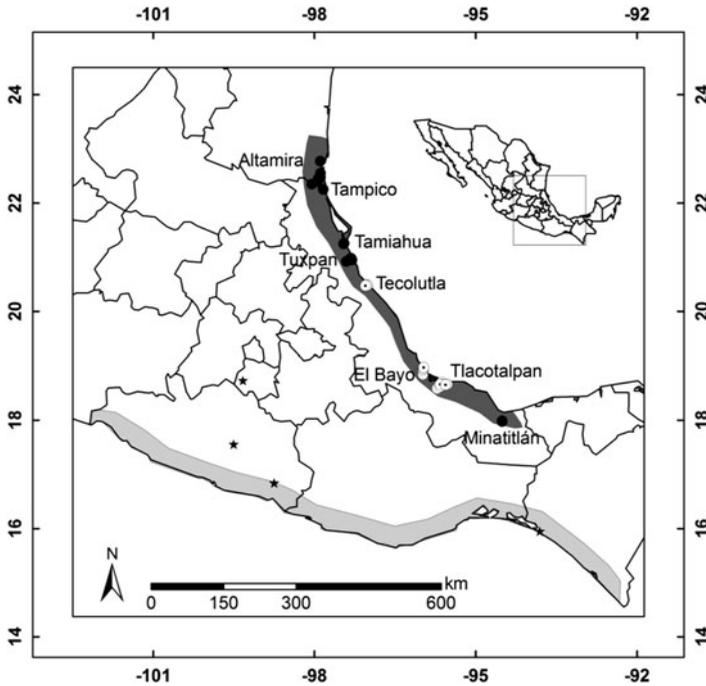
Figure 1. Geographical distribution of Fuertes's Oriole, the dark grey polygon represents breeding distribution and the light grey polygon the winter distribution as suggested by Howell and Webb (1995). The black and white circles represent currently known historic localities of the bird, although the latter correspond to the localities visited in this study (see Methods). The stars indicate examples of dubious records of the species during the non-breeding season.

excellent tool for improving conservation strategies for taxa that are rare or difficult to locate (Peterson *et al.* 2002, Peterson and Papes 2006, Franklin 2009, Peterson *et al.* 2011, Mota-Vargas *et al.* 2013), as is the case with Fuertes's Oriole, that are in addition facing unprecedented reductions in their natural environment (Kiere *et al.* 2007).

Due to the scarcity of information, the objectives of this study were to analyse the geographical and temporal distribution of the species using ENM, to make an assessment of the species' abundance, and based on this information, discuss the implications for its conservation.

Methods

Occurrence data

Information about species occurrence was obtained from three sources; the first comprised an exhaustive search of historical records in available databases (Global Biodiversity Information Facility [GBIF; http://www.gbif.org/], the Avibase database [http://avibase.bsc-eoc.org]) as well as consultation of the atlas of the birds of Mexico (Navarro-Sigüenza *et al.* 2003). Historical records with no geospatial information were geo-referenced (latitude–longitude) with the use of electronic gazetteers (http://manisnet.org/gci2.html, http://www.biogeomancer.org) as well as data from the National Institute of Statistic and Geography (INEGI 2011). Occurrence data were also gathered from published records in peer-reviewed journals and specialised literature (Chapman 1911, Graber and Graber 1954, Dickerman 1964, Howell and Webb 1995, Jaramillo and Burke 1999, Kiere *et al.* 2007, Martin and Omland 2011). When no coordinates were provided, we georeferenced

them as above. A third source of information was derived from field surveys to search for the species in localities where there had been previous reports and in surrounding areas in order to update the current state of knowledge regarding abundance, as well as in other intermediate regions between known localities in order to add more occurrence records; these records were geo-referenced using a global positioning system (GPS).

As part of the historical records review, we examined specimens collected in the states of Morelos and Guerrero, in the collections of the American Museum of Natural History (AMNH Bird SKIN-818329) and the Museum of Zoology of the Faculty of Sciences at the UNAM (MZFC 16544) in Mexico. Photographs were also checked via the internet in order to verify sightings of the species in the state of Chiapas, (http://ibc.lynxeds.com/species/fuertess-oriole-icterus-fuertesi).

Dubious historical records, particularly those with no specimens or photographic evidence, and those that were duplicates or offered insufficient geographic information for geo-referencing (i.e. ambiguous localities), were eliminated. After this careful revision, we gathered a total of 179 unique records (latitude–longitude; hereafter referred to as sites). However, given that almost 70% of them were located less than 1 km apart, and considering that spatial autocorrelation could bias the modelling performance, for those areas with high concentration of records (particularly during the breeding season in Tecolutla and Tlacotalpan) we randomly eliminated 50% of them. Thus, we obtained a final set of 43 sites, 40 for the breeding season and five for the non-breeding season (please note that the sum does not correspond to 45 due to the duplication of two sites for breeding and the non-breeding seasons; Table S1 in the online supplementary material). Data visualisation and edition were carried out in ArcView v. 3.1 (ESRI 1999).

Environmental data

For the environmental characterisation of each season, we used three monthly climatic variables, available via digital maps from WorldClim project (Hijmans *et al.* 2005) and obtained for each season. These showed maximum and minimum temperatures and average precipitation, in combination with three topographic variables: elevation, slope and topographic index (CTI), from the Hydro 1K Project (USGS 2001). All layers had a resolution of 0.0083° (~ 1 km²).

Ecological niche modelling

Analysis of geographical, ecological and seasonal distribution was performed using ENM. The niche models relate records of species occurrence with abiotic variables, in order to detect areas with environmental factors favouring the presence of the species (Peterson *et al.* 2002, 2011). In this study we used the algorithm MaxEnt V. 3.3.3e (Phillips *et al.* 2006) to obtain potential geographic and seasonal distributions and niche characterisation for Fuertes's Oriole, as previous studies have shown that this is a suitable algorithm for making predictions, especially when considering a small number of presence records (Phillips *et al.* 2006, Pearson *et al.* 2007).

MaxEnt estimates the probability of distribution that has maximum entropy applying the following principle: the expected value for each ecological (in this case, climatic and geomorphological) variable must equal the empirical average, i.e. the average value for points relating to known presence. The algorithm performs a certain number of iterations until reaching a convergence limit. The final map represents a favourability rating ranging from 0 (unsuitable) to 1 (perfectly adequate) (Phillips *et al.* 2006). We used the predetermined settings in the program, although the "Do clamping" and "extrapolate" options were disabled in order to avoid artificial extrapolations for the most extreme values among the ecological variables.

In order to analyse patterns of seasonal distribution of the species, based on variations in terms of date of occurrence records throughout the year, two groups of layers were drawn up in terms of climatic variables, which in turn corresponded to the breeding and non-breeding seasons. Although the breeding season of the species is mainly the period from May to July (Jaramillo and

Burke 1999, Martin and Omland 2011), in this study, we expanded it to the period between March and August. This was based on the observation of active nests in mid-March and mid-August in some localities throughout the species distribution (Table S1). The non-breeding season consisted of the months of November, December and January. September, October and February were not considered in this analysis due to lack of records, as these are apparently months of transition in which migration takes place.

Three MaxEnt models were constructed: one each for the breeding season and non-breeding season and one for the breeding season, but restricted to northern records. For each model, a map of the potential distribution of the climatic niche was produced (autopredictions) and models from one season were also used to predict distribution in the other season (allopredictions): projected non-breeding season distribution, based on breeding season model; projected breeding season distribution, based on the non-breeding season model; and projected non-breeding season distribution, based on the northern breeding season localities. Projections are transferences of the ecological niches calibrated in a particular seasonal scenario to another seasonal scenario and are performed directly in MaxEnt. This approach allowed an assessment of the degree to which the species maintains consistent conditions between seasons (*niche-follower* species, as defined by Nakazawa *et al.* 2004), and determines whether the species migrate from the Gulf of Mexico to the Pacific coastal plain (as has been historically suggested).

The performance of the models resulting from MaxEnt are traditionally evaluated using a ROC curve (Receiver Operating Characteristic curve; Phillips *et al.* 2006) a statistical technique that has become a predominant tool in evaluating the accuracy of models predicting species' distributions (Elith *et al.* 2006). However, several problems have been associated with this technique (Peterson *et al.* 2008, Lobo *et al.* 2008). One of them is that the two error components (omission and commission) are inappropriately weighted equally. Accordingly, we use a modification of ROC analyses that solves these problems: partial-area ROC approaches that evaluate only over the spectrum of the prediction and that allow for differential weighting of the two error components (Peterson *et al.* 2008, Williams and Peterson 2009). Thus, we carried out partial ROC analyses for each model. AUCs were limited to the proportional areas over which models actually made predictions and only omission errors of < 5% were considered (Peterson *et al.* 2008). We calculated partial AUCs using the Tool for Partial-ROC V. 1.0 (Barve 2008) using 25% of the original data for independent model evaluation. Thus, for the breeding season we used 30 data points for model performance and 10 for testing and for the breeding season of the northern localities, 16 data points were used for model performance and five for testing. We presented our ROC results as the ratio of the model AUC to the null expectation ("AUC ratio"; Peterson *et al.* 2008). Bootstrapping manipulations to permit evaluation of statistical significance of AUCs (as compared with null expectations) were achieved by resampling 50% of the points with replacement 1,000 times from the overall pool of data; one-tailed significance of differences in AUC (i.e. elevation above the line of null expectation) was assessed by counting the number of bootstrap replicates with AUC ratios < 1.

Because the number of sites for the non-breeding season was limited, we applied the jackknife validation approach suggested by Pearson *et al.* (2007) to assess the ability to predict species occurrence when few occurrence records are available, where multiple predictions (five from our database) were made with one of the observed site excluded in each case. For each prediction, two threshold decisions (minimum training presence and fixed cumulative value of 10) were applied, and the ability to predict the excluded locality was tested. A *P*-value was then calculated for the overall model across the set of jackknife predictions using the script made by Pearson *et al.* (2007).

Habitat and analysis of abundance

We describe the habitat associated with the presence of this species during field surveys in the localities visited (Tecolutla, El Bayo and Tlacotalpan). In addition an estimate and comparison of the relative abundance of the species was made in two localities with the greatest number of historical sites

of presence: 1) Tecolutla (20°29'N, 97°00'W), located in the northern part of the state of Veracruz, and visited during the months of May, August, December 2011 and January 2012, and 2) Tlacotalpan (18°36'N, 95°39'W), located in southern Veracruz, and visited during the months of March, May, July and December 2011. These two localities consist of wetlands dominated by semi-urban zones, flooded grassland with introduced grasses, hedges, small fragments of mangrove forest (sometimes grown as live fences in Tecolutla) and areas with citrus crops, for the most part.

To estimate relative abundance, a modification of the method of point counts by Ralph *et al.* (1996) was followed, which consisted of defining fixed observation points every 200 m for a distance of 2 km, reaching a total of 10 observation points at each locality. This count was repeated 14 times in Tlacotalpan (10 in the breeding season and four in the non-breeding season) and six times in Tecolutla (four in the breeding season and two in the non-breeding season). Reproducing birdsong (playback) increases the probability of detecting a species and allows efficient monitoring of the population (Sutherland 2006); thus we produced a playback of the song using an amplifier and sound player, and in order to avoid abrupt cessation of singing, this was programmed on auto-repeat mode. The song playback consisted of two sets of calls of 30 seconds each, separated by 30 seconds of silence. The sample was maintained at a constant, permitting the calculation of an index of relative abundance derived from the sum of all point counts by season and locality; this index consisted in dividing the total sum of all individual sightings, by the total sum of point–counts. The surveys were conducted in the morning (06h00–10h00) and afternoon (16h00–20h00).

Results

Geographic and ecological distribution

We obtained a final set of 43 sites referring to spatially unique sightings associated with eight localities, 40 for the breeding season, and five for the non-breeding season (Table S1). The latter records correspond to localities already known for the breeding season; however, as a result of fieldwork searches, the first winter records for the species in these same localities were obtained (in the Gulf area).

It was confirmed that all specimens from Morelos and Guerrero were juveniles and female individuals, making it difficult to correctly identify them (Fuertes's Oriole is morphologically indistinguishable from Orchard Oriole except in the case of male adults) so they were not considered for the ENM, but this fact also queries the winter migration to the Pacific, as these records may refer to Orchard Oriole. Besides this, we examined the photograph taken by S. Howell in Puerto Arista, Chiapas (Howell and Webb 1995); it was concluded that the quality of the image made correct identification difficult, as the bird photographed appeared to be similar to a juvenile male Baltimore Oriole *I. galbula*; thus this record was not taken into account for the ENM either.

We used the MTP threshold, with a predicted probability of 0.1, based on the confidence for all occurrence dataset used to generate the models. The potential distribution of the species obtained for the breeding season (Figure 2a) covered an area close to the coast of the Gulf of Mexico, particularly the northern area which comprises flood-plains and mangrove swamps (with a high degree of disturbance), similar to that which extends inland along the Tamesí River, bordering the state of Veracruz and Tamaulipas, as well as that going south along the Papaloapan River. Projection (transference of ecological conditions) of the ENM from the breeding season into the winter season (Figure 2b) indicated that it is present in a small area corresponding to Tlacotalpan and Minatitlán.

The ENM for the non-breeding season (Figure 2c) indicated a potential distribution of the species during the breeding season in southern Veracruz, encompassing the localities of El Bayo, Tlacotalpan and Minatitlán, although with low probability. Significantly, only a small portion was predicted for the Pacific coast, in the Isthmus of Tehuantepec, in the state of Oaxaca. Winter conditions in localities showing presence during the non-breeding season projected to the breeding season (Figure 2d) coincided with the distribution of the species in northern localities, suggesting that the climatic conditions relating to the potential distribution during the breeding season in the north are very similar to those found during the winter in the southern localities, as demonstrated when we
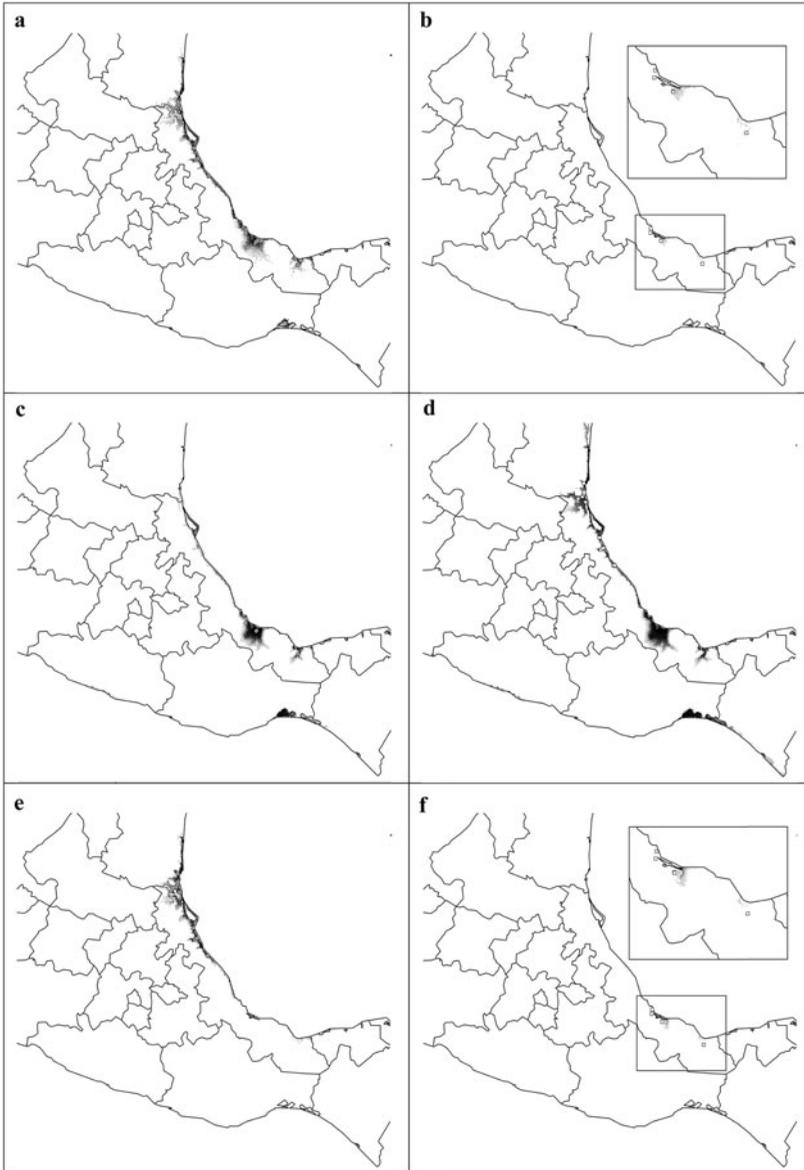
Figure 2. Potential distribution of ecological niche of the species by seasons: a) breeding season model; b) predicted distribution in non-breeding season, based on breeding season model; c) non-breeding season model; d) predicted distribution in breeding season, based on non-breeding season model; e) breeding season for sites in northern Veracruz, and f) predicted distribution in the non-breeding season, based on the breeding season model restricted to sites in northern Veracruz. Shading corresponds to the probability threshold of the minimum training presence (MTP) of 0.1 (light grey) to the maximum predicted probability of 0.9 (black); areas predicted by the model below 0.1 of MTP threshold were not considered. Dots represent localities used for ENM. The white squares in "b" and "f" are localities from the non-breeding season, but in "d" they symbolize the absence of the species in winter, but are associated with presence in localities during the breeding season.

modelled the distribution of the species considering only the northern localities during the breeding season (Figure 2e), and when it became the opposite, i.e. when these conditions were projected to geographical winter, these coincided with southern localities (Figure 2f); albeit with low probability. For each model the variables with higher percentage of contribution according to MaxEnt were: altitude (50.3%) for the breeding season; TMIN (55.4%) for the non-breeding season; and altitude (50.5%) for the northern breeding season respectively (Table 1).

When we modelled the potential distribution for the climatic niche of the species during the breeding season, the resulting area covered approximately 18,871 km², whereas the potential distribution of the climatic niche occupied in the non-breeding season, was only c.4,250 km²; areas predicted by the model below the MTP threshold were not considered. Results indicated areas with favourable climatic conditions for the potential presence of the species in Tabasco and Yucatan peninsula, but these areas were omitted from the analysis because they did not have either current or historical records validating the presence of the species in these areas, although the possibility of annual or even seasonal presence in low densities was not ruled out; this will require more intensive searches in order to clarify its presence in the region.

The performance of the two models for the breeding season (Figure 2 a,e) and their respective projections (Figure 2 b,f) based on the results from the partial ROC curves, in both cases was significantly greater than expected at random, indicating for the breeding season model an AUC ratio of 1.98 ($P < 0.001$) and for the breeding season model for northern localities an AUC ratio of 1.99 ($P < 0.001$).

On the other hand, the performance of the projected potential distribution model of the non-breeding season model (Figure 2 c) and its projection (Figure 2 d) showed high and significant success rates in the jackknife tests with a threshold of 10% from the fixed cumulative value (T10 = 0.17, $P = 0.02$), rather than the minimum training presence (MTP = 0.40, $P = 0.66$). The minimum training presence approach (MTP) can be interpreted ecologically as identifying pixels predicted as being at least as suitable as those pixels where the species has been recorded, whereas the fixed cumulative value approach (T10) rejected only the lowest 10% of possible predicted values in the model (Pearson *et al.* 2007). Thus, the last approach in this case was less conservative and strict than the MTP, in which a larger predicted area is incorporated through the model.

Table 1. Relative contributions of the environmental variables to the MaxEnt models. Variable descriptions are as follows: tmax–maximum temperature, tmin–minimum temperature, prec–mean precipitation, dem–digital elevation model, slope–slope, and topoind–compound topographic index (a function of upstream contributing area and slope that reflects tendency to pool water).

Model	Variable	Percent contribution
Breeding season	dem	50.3
	tmin	35.9
	tmax	7.8
	prec	2.9
	slope	2.8
	topoind	0
Non-breeding season	tmin	55.4
	dem	39.9
	tmax	4.2
	slope	0.4
	prec	0.2
	topoind	0
Northern breeding season	dem	50.5
	tmin	26.9
	tmax	11.7
	slope	6.9
	prec	4
	topoind	0.1

However, despite a change in total area, the T10- and MTP-based assessments were comparable, allowing us to use the non-breeding season model with confidence.

Habitat and estimate of abundance

Information about the specific type of habitat of Fuertes's Oriole is also unclear. It has been suggested that during the breeding season its habitat corresponds to the dense shrubbery of coastal sand-dunes (Chapman 1911, Graber and Graber 1954); however, according to Jaramillo and Burke (1999) and field observations made during this study, the species is now only found associated with open sites on the margins of agricultural land, secondary vegetation, urban areas and scrubby thickets of bull's horn acacia *Acacia* sp.

We observed that the individuals of *I. fuertesi*, when present in the sites always responded to the playback, showing aggressive behaviour, particularly the males; however, females and juveniles also responded by approaching the speaker. On the contrary, *I. spurius* that was always observed in large groups (> 40 individuals) did not respond to the *I. fuertesi* calls, helping us to avoid misidentifications during the observations.

The results of the relative abundance index showed similar values for both localities Tlacotalpan and Tecolutla for the breeding season (0.40 and 0.48 respectively); however, for the non-breeding season the abundance index decreases dramatically showing very low value in Tlacotalpan (0.12) and zero in Tecolutla (Table 2). The number of males was almost twice that of females or juveniles for both localities and seasons.

Discussion

There is an evident lack of up-to-date knowledge relating to Fuertes's Oriole, when the inaccuracies of the records concerning their geographical and seasonal distribution are considered; a fact that is troubling considering that this represents a Mexican micro- endemic species. This ignorance may be partly due to slow progress in terms of recognising this bird as a taxonomically distinct evolutionary lineage (Baker *et al.* 2003). If this is the case, it would have important implications for conservation, especially as the size of the distribution area of a species is considered as an important criterion when determining their risk category (IUCN 2012, Sánchez *et al.* 2007, SEMARNAT 2010). In this case, it would be restricted to a few localities along the Gulf coast of Mexico.

Since the description by Chapman (1911), few studies have focused on understanding the biology of this species, despite it being endemic to Mexico and assigned a low risk category under Mexican legislation (NOM-059-2010, SEMARNAT 2010). Thus this study provides fundamental information for understanding the spatial and seasonal distribution of the species, considering the challenge presented by a migratory bird, which has seasonal variations in distribution.

Table 2. Number of individuals recorded at each locality and by seasons, together with the index of relative abundance.

	Category	Breeding season			Non-breeding season		
		No. fixed points	No. birds	index	No. fixed points	No. birds	index
Tlacotalpan	Juveniles		13	0.13		1	0.025
	Males		21	0.21		4	0.1
	Females		14	0.14		0	0
	Total	100	48	0.48	40	5	0.12
Tecolutla	Juveniles		3	0.075		0	0
	Males		12	0.3		0	0
	Females		1	0.025		0	0
	Total	40	16	0.4	20	0	0

This study found that the species is characterised by a very limited potential distribution area along the coast of the Gulf of Mexico, in the states of Tamaulipas and Veracruz, and was reported to occupy an area eight times smaller than previously reported by Martin and Omland (2011), who estimated an area of potential distribution in the breeding season of 145,400 km² using an ENM in a study comparing the distribution of Orchard Oriole and Fuertes's Oriole. Differences in the estimates may be due to fact that in the study by Martin and Omland (2011) annual environmental variables were used to model seasonal distribution. Our results, obtained by separating seasonal variations, are of particular relevance and cause concern about the conservation of Fuertes's Oriole, because distribution is suggested to cover an area less than 50,000 km²; thus, while areas predicted from ENM should be considered with caution, the magnitude of the difference is notable, making this species a conservation priority (ICBP 1992, Stattersfield *et al.* 1998).

Likewise, fieldwork to search for new localities of the species was unsuccessful, with eight known localities remaining for the breeding season, with some new records which are relatively close to already known localities (e.g. Salinas, Veracruz at a distance of 6 km from El Bayo), and with only three known localities during their non-breeding season (although associated with five sites; Table S1). This suggests that the distribution of this species is particularly restricted, and strongly isolated with a lack of connectivity between geographic localities. However, the use of ENM allowed the filling in of potential gaps to asses a more comprehensive distributional hypothesis based on a low number of known presence localities ($n > 15$), as has been used in other examples (Papes and Gaubert 2007, Pearson *et al.* 2007, Sandoval-Comte *et al.* 2012).

The results also suggest, however, the necessity for more intensive fieldwork in non- or poorly surveyed areas, focusing on both breeding and winter periods. Given the uncertainty about the non-breeding range, as is the case of the southernmost distributional range, such fieldwork should be particularly directed towards areas where there are very few observations (e.g. the surroundings of Minatitlán): This will complement and improve modelling as well as conservation strategies.

Besides the restricted and fragmented geographic distribution, the seasonal patterns of the species' distribution remains unclear, because it was long thought to make winter migrations to the Pacific coastal plain (Howell and Webb 1995, Jaramillo and Burke 1999) and that distribution extended to the state of Guerrero (Blake 1953, Howell and Webb 1995, Jaramillo and Burke 1999). However, the ENM analysis suggests that the species makes a winter migration (corresponding in this study to the non-breeding season) consisting of a short north to south movement in the Gulf of Mexico and corresponding with the southern areas during the breeding season. It is important to note that according to Nakazawa *et al.* (2004) there is a variation in terms of the seasonal ecology of migratory species, some follow a particular climate niche between seasons ("niche followers"), whereas others make changes in their climatic regimes between seasons ("niche switchers"). If Fuertes's Oriole is a niche-follower, then there is no climatic evidence to suggest that species migrates to the Pacific in winter, as the projections of niche models from the breeding area (coastal area along the Gulf of Mexico) to the months of the non-breeding season, show that these weather conditions do not exist on the Pacific coast during the non-breeding season, except in the case of a small area of the Pacific coast on the Isthmus of Tehuantepec and in the northern area of Chiapas state (Figure 2d) and that actually coincide with one dubious photographic record (Howell and Webb 1995) from Puerto Arista, Chiapas, which might suggest the species occurs along this reduced length of Pacific coastline.

Conversely, if the species is a niche switcher, as possibly suggested by the dubious historical records of the species in the central area and along the Pacific coast, this would uphold the possibility of a Gulf-Pacific migration. However, careful analysis of the specimens stored in scientific collections, suggest they are juveniles and/or females, so there is no certainty in terms of their identification or their presence in these areas during the winter. This reveals a need to continue the intensive search for this species in the Pacific area, although our results suggest that Fuertes's Oriole is a short distance migratory species ("niche follower"). Furthermore, the absence of records indicating occurrence in the north of its known distribution in the Gulf of Mexico during the non-breeding season, also upheld by the results from the ENM, suggests that populations from northern Veracruz and southern Tamaulipas, may undertake only one winter migration to

southern Veracruz, where likewise we find the first confirmed winter records, corresponding to those found in southern areas during the breeding season, where it was observed that weather conditions exist for the annual presence of this species (Figure 2c–f).

The relative abundance index values obtained in this study during the breeding season recorded an average of four individuals for each 10 points, although this value is perhaps influenced by the use of playback that most probably increased detection (Sutherland 2006). On the contrary, for the non-breeding season, the lower values of relative abundance index could also arise from birds not responding to playback; the same could have occurred with the number of individuals by sex and age, with males being the most recorded (Table 2), although the obtained values might be comparable between localities within the same season. However, since the relative abundance index was estimated only for two localities, we are not able to make any suggestion regarding the total population size. It is, however, important to note that the geographical patterns of distribution (including the currently known localities and the predicted areas) suggest an important degree of isolation among populations within the breeding season, where the flow of individuals is unlikely.

Evaluation of risk status

Based on the results obtained in this study, the estimated extent of occurrence is severely fragmented and restricted to less than 20,000 km², with isolated populations containing low number of individuals. Implications for populations using disturbed habitats are unknown, but Kiere *et al.* (2007) have pointed out that the loss or alteration of habitat, which is apparently already very restricted, could have a dramatic effect on reproductive possibilities. Besides, according to our description, it is apparent that the species may be facing a situation of unprecedented risk considering that the impacts of human activity are causing a continuing decline in area, extent and quality of habitat; thus, we suggest re-evaluation of the risk status of this species. IUCN (2012) use several criteria to assess risk status, including the size of geographical distribution and population size, which is inversely correlated to the probability of extinction; therefore, under IUCN criteria it corresponds at least to the category of 'Vulnerable', perhaps higher. The criteria under Mexican legislation for defining species' risk categories (Sánchez *et al.* 2007) includes the extent of distribution, the state of habitat, the intrinsic biological vulnerability, and the potential impact of human activities; thus, the category for Fuertes's Oriole fully complies with the Mexican threatened category.

Finally, although there are programmes and conservation initiatives for some localities, e.g. Tecolutla and Tlacotalpan have been considered as Important Areas for Bird Conservation (Arizmendi and Márquez 2000) as well as Ramsar Sites (http://www.ramsar.org), it is known that the other localities where the species is recorded, are suffering a high degree of human impact and degradation, and in turn are subject to intense stochastic events such as flooding and hurricanes (Moreno-Casasola 2011); thus special attention needs to be paid to the conservation of this species.

Supplementary Material

The supplementary material for this article can be found at journals.cambridge.org/bci

internet: Delaware Museum of Natural History, American Museum of Natural History, Royal Ontario Museum, Florida Museum of Natural History, Instituto de Biología-UNAM, Museo de Zoología Facultad de Ciencias-UNAM. ATS received a CONACyT scholarship for a Master's thesis.

References

AOU (1983) *Check-list of North American birds*. Sixth edition. Washington, DC: American Ornithologists' Union.

AOU (1998) *Check-list of North American birds*. Seventh edition. Washington, DC: American Ornithologists' Union.

Arizmendi, M. C. (2003) Estableciendo prioridades para la conservación de las aves. Pp. 133–149 in H. Gómez de Silva and A. Oliveras de Ita, eds. *Conservación de aves, experiencias en México*. México, D.F.: CIPAMEX, National Fish and Wildlife Fundation, CONABIO.

Arizmendi, M. C. and Márquez, L. (2000) *Áreas de importancia para la conservación de las aves en México*. México, D.F.: CIPAMEX.

Baker, J. M., López-Medrano, E., Navarro-Sigüenza, A. G., Rojas-Soto, O. R. and Omland, K. E. (2003) Recent speciation in the orchard oriole group: divergence of *Icterus spurius spurius* and *Icterus spurius fuertesi*. *Auk* 120: 848–859.

Barve, N. (2008) *Tool for partial-ROC*. Biodiversity Institute, Lawrence, KS. V. 1.0.

BirdLife International (2000) *Threatened birds of the world*. Barcelona, Spain and Cambridge, UK: Lynx Edicions and BirdLife International.

Blake, E. R. (1953) *Birds of Mexico*. Chicago: University of Chicago Press.

Chapman, F. M. (1911) Description of a new oriole (*Icterus fuertesi*) from Mexico. *Auk* 28: 1–4.

Clements, J. F., Schulenberg, T. S., Iliff, M. J., Sullivan, B. L., Wood, C. L. and Roberson, D. (2012) *The eBird/Clements checklist of birds of the world*: V. 6.7. http://www.birds.cornell.edu/clementschecklist/downloadable-clements-checklist.

Dickerman, R. W. (1964) A specimen of Fuertes's Oriole, *Icterus fuertesi* from Texas. *Auk* 81: 433.

Elith, J. H., Graham, C. P., Anderson, R., Dudik, M., Ferrier, S., Guisan, A. J., Hijmans, R., Huettmann, F. R., Leathwick, J., Lehmann, A., Li, J. G., Lohmann, L. A., Loiselle, B., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., McC Overton, J., Peterson, A. T., Phillips, S., Richardson, K., Scachetti-Pereira, R., Schapire, R., Soberon, J., Williams, S. S., Wisz, M. and Zimmermann, N. (2006) Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29: 129–151.

ESRI (1999) *ArcView GIS*, V. 3.2. California, USA: Environmental Systems Research Institute Inc.

Franklin, J. (2009) *Mapping species distributions: spatial inference and prediction*. Cambridge, UK: Cambridge University Press.

Gill, F. and Donsker, D., eds. (2012) *IOC world bird names*. V. 3.2. (accessed July 2012).

González-García, F. and Gómez de Silva, H. (2003) Especies endémicas: riqueza, patrones de distribución y retos para su conservación. Pp. 150–194 in H. Gómez de Silva and A. Oliveras de Ita, eds. *Conservación de aves, experiencias en México*. México, D.F.: CIPAMEX, National Fish and Wildlife Fundation, CONABIO.

Graber, R. R. and Graber, J. W. (1954) Comparative notes on Fuertes's and Orchard orioles. *Condor* 56: 274–282.

Hess, P. (2004) Orchard Oriole split suggested. *Birding* 36: 464.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G. and Jarvis, A. (2005) Very high resolution interpolated climate surfaces for global land areas. *Internatn. J. Climatol.* 25: 1965–1978.

Howell, S. N. G. and Webb, S. (1995) *A guide to the birds of Mexico and northern Central America.* New York: Oxford University Press.

ICBP (1992) *Putting biodiversity on the map: priority areas for global conservation*. Cambridge, UK: International Council for Bird Preservation.

INEGI (Instituto Nacional de Estadística, Geografía e Informática) (2011) http://www.inegi.gob.mx (accessed March 2012).

IUCN (2012) *IUCN Red List categories and criteria: v. 3.1*. Second edition. Gland, Switzerland and Cambridge, UK: IUCN.

Jaramillo, A. and Burke, P. (1999) *New World blackbirds: The Icterids*. Princeton, NJ: Princeton University Press.

Jiménez-Valverde, A. Peterson, A. T., Soberón, J., Overton, J. M., Aragón, P. and Lobo, J. M. (2011) Use of niche models in invasive species risk assessments. *Biol. Invasions* 13: 2785–2797.

Kiere, L. M., Hofmann, C. M., Tracy, I. E., Cronin, T. W., Leips, J. and Omland, K. E. (2007) Using the color to define species boundaries: quantitative analysis in the orchard oriole complex supports the recognition of two species. *Condor* 109: 692–697.

Lobo, J. M., Jiménez-Valverde, A. and Real, R. (2008) AUC: a misleading measure of the performance of predictive distribution models. *Global Ecol. Biogeog.* 17: 145–151.

Marini, M. A., Barbet-Massin, M., Esteves, L. and Jiguet, F. (2009) Predicted climate-driven bird distribution changes and forecasted conservation conflicts in a Neotropical savanna. *Conserv. Biol.* 23: 1558–1567.

Martin, M. D. and Omland, K. E. (2011) Environmental niche modeling reveals climatic differences among breeding ranges of orchard oriole subspecies. *Am. Midl. Nat.* 166: 404–414.

Martínez-Meyer, E., Peterson, A. T., Servín, J. I. and Kiff, L. F. (2006) Ecological niche modelling and prioritizing areas for species reintroductions. *Oryx* 40: 411–418.

Martínez-Morales, M. A., Zuria, I., Chapa-Vargas, L., MacGregor-Fors, I., Ortega-Álvarez, R., Romero-Águila, E. and Carbó, P. (2010) Current distribution and predicted geographic expansion of the Rufous-backed Robin in Mexico: a fading endemism? *Divers. Distrib.* 16: 786–797.

Moreno-Casasola, P., Infante, D. M., López-Rosas, H., Peralta, L. A., Castillo-Campos, G., Travieso-Bello, A. C., Méndez, W. A., and Sánchez-Ríos, G. (2011) La biodiversidad de los humedales. Pp. 217–228 in Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) *La biodiversidad en Veracruz: estudio de estado*. México: CONABIO, Gobierno del Estado de Veracruz, Instituto de Ecología, A.C.

Mota-Vargas, C., Rojas-Soto, O. R., Lara, C., Castillo-Guevara, C. and Ballesteros-Barrera, C. (2013) Geographic and ecological analysis of the Bearded Wood Partridge *Dendrortyx barbatus*: some insights on its conservation status. *Bird Conserv. Internatn.* 23: 371–385.

Nakazawa, Y., Peterson, A. T., Martínez-Meyer, E. and Navarro-Sigüenza, A. G. (2004) Seasonal niches of Nearctic-Neotropical migratory birds: implications for the evolution of migration. *Auk* 121: 610–618.

Navarro-Sigüenza, A. G. and Peterson, A. T. (2004) An alternative species taxonomy of Mexican birds. *Biota Neotropica* 2: 1–32.

Navarro-Sigüenza, A., Peterson, A. T. and Gordillo-Martínez, A. (2003) Museums working together: the atlas of the birds of Mexico. *Bull. Brit. Ornithol. Club Suppl.* 123A: 207–225.

Omland, K. E. and Lanyon, S. M. (2000) Reconstructing plumage evolution in orioles (*Icterus*): repeated convergences and reversal in patterns. *Evolution* 54: 2119–2133.

Ortega-Huerta, M. A. and Peterson, A. T. (2004) Modelling spatial patterns of biodiversity for conservation prioritization in north-eastern Mexico. *Divers. Distrib.* 10: 39–54.

Papes, M. and Gaubert, P. (2007) Modelling ecological niches from low numbers of occurrence: assessment of the conservation status of poorly known viverrids (Mammalia, Carnivora) across two continents. *Divers. Distrib.* 13: 890–902.

Pearson, R. G., Raxworthy, C. J., Nakamura, M. and Peterson, A. T. (2007) Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. *J. Biogeogr.* 34: 102–117.

Peterson, A. T. and Papes, M. (2006) Potential geographic distribution of the Bugun Liocichla *Liocichla bugunorum*, a poorly-known species from north-eastern India. *Indian Birds* 6: 148–151.

Peterson, A. T., Ball, L. G. and Cohoon, K. P. (2002) Predicting distribution of Mexican birds using ecological niche modelling methods. *Ibis* 144: e27–e32.

Peterson, A. T., Papes, M. and Soberón, J. (2008) Rethinking receiver operating characteristic analysis applications in ecological niche modeling. *Ecol Modell.* 213: 63–72.

Peterson, A. T., Sánchez-Cordero, V., Soberón, J., Bartley, J., Buddemeier, R. W. and Navarro-Sigüenza, A. G. (2001) Effects of global climate change on geographic distributions of Mexican Cracidae. *Ecol. Modell.* 144: 21–30.

Peterson, A. T., Soberón, J., Pearson, R. G., Anderson, R. P., Martínez-Meyer, E., Nakamura, M. and Bastos, M. (2011) *Ecological niches and geographic distribution.* Princeton, NJ: Princeton University Press.

Phillips, S. J., Anderson, R. P. and Schapire, R. E. (2006) Maximum entropy modeling of species geographic distributions. *Ecol. Modell.* 190: 231–259.

Ralph, C. J., Geupel, G. R., Pyle, P., Martin, T. E., Sante, De, D. F. and Milá, B. (1996) *Manual de métodos de campo para el monitoreo de aves terrestres.* Albany, California: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Gen. Tech. Rep. PSW-GTR-159.

Rodríguez, J. P., Brotons, L., Bustamante, J. and Seosane, J. (2007) The application of predictive modelling of species distribution to biodiversity conservation. *Divers. Distrib.* 13: 243–251.

Rojas-Soto, O. R., Navaro-Sigüenza, A. G. and Espinosa de los Monteros, A. (2010) Systematics and bird conservation policies: the importance of species limits. *Bird Conserv. Internatn.* 20: 176–185.

Sánchez, O., Medellín, R., Aldama, A., Goettsch, B., Soberón, J. and Tambutti, M. (2007) *Método de evaluación del riesgo de extinción de las especies silvestres en México (MER).* México, D.F.: SEMARNAT, Instituto Nacional de Ecología, UNAM, CONABIO.

Sandoval-Comte, A., Pineda, E. and Aguilar-López, J. L. (2012) In search of critically endangered species: the current situation of two tiny salamander species in the neotropical mountains of Mexico. *PLOS One.* 7: e34023. doi:10.1371/journal.pone.0034023

SEMARNAT (2010) Diario Oficial de la Federación (2010) *Norma Oficial Mexicana NOM-059-2010. Protección ambiental, especies nativas de México de flora y fauna silvestres, categorías de riesgo y especificaciones para su inclusión, exclusión o cambio. Lista de especies en riesgo.* México, D.F.: Secretaría de Medio Ambiente y Recursos Naturales. Secretaría de Gobernación.

Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998) *Endemic bird areas of the world. Priorities for biodiversity conservation.* Cambridge, UK: BirdLife International (BirdLife Conservation Series 7).

Sutherland, W. J. (2006) *Ecological census techniques.* Second edition. Cambridge, UK: Cambridge University Press.

UNEP-WCMC (Comps.) (2001) *Checklist of CITES species* (CD-ROM). Geneva, Switzerland, and UNEP-WCMC, Cambridge, UK: CITES Secretariat. http://www.cites.org/eng/resources/species.html (accessed July 2012).

USGS (2001) HYDRO1k Elevation Derivative Database. Washington, DC: U.S. Geological Survey. http://edcdaac.usgs.gov/gtopo30/hydro/ (accessed January-August 2011).

Williams, R. A. J. and Peterson, A. T. (2009) Ecology and geography of avian influenza (HPAI H5N1) transmission in the Middle East and northeastern Africa. *Internatn. J. Health Geographics.* 8: 47.

Williams, K. A., Westphal, M. I., Possingham, H. P. and Elith, J. (2005) Sensitivity of conservation planning to different approaches to using predicted species distribution data. *Biol. Conserv.* 122: 99–112.

ARIADNA TOBÓN-SAMPEDRO, OCTAVIO R. ROJAS-SOTO*
Red de Biología Evolutiva, Instituto de Ecología, A. C., Km. 2.5 carretera antigua a Coatepec 351, El Haya, Xalapa, Veracruz, 91070, México.

*Author for correspondence; e-mail: octavio.rojas@inecol.mx