Habitat modeling of the common pheasant *Phasianus colchicus* (Galliformes: Phasianidae) in a highly modified landscape: application of species distribution models in the study of a poorly documented bird in Iran

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Abstract

The common pheasant is listed as a nationally protected species in Iran because it faces many threats such as habitat destruction, pollution from pesticides and overhunting. The species’ habitat selection remains unknown in Iran; consequently, conservation planning for the species is hampered by this lack of information. In this study we used predictor variables including topographic, anthropogenic, land cover and climate and 122 occurrence points to model the distribution of common pheasant (subspecies *P. c. talischensis*), in Gilan province, Iran. The results showed that distance to agriculture and orchards as well as distance to plantation forests were the most important variables in predicting species distribution. Furthermore, we found that the total potential suitable habitat for the species in Gilan province is 315,990 hectares. We observed a shift of the species to higher altitudes in the province. We recommend raising awareness about the presence of the species especially among private landowners, creating a network of protected areas on private land, and changing land-use policies at the provincial level as essential measures for the conservation of the species in Gilan province. Our results can be applied to management and conservation of the species in other modified or rapidly changing landscapes.

Keywords: Avian ecology, avian conservation, distribution, Maxent, Iran

Introduction

Natural habitats are rapidly changing worldwide; therefore, persistence of biodiversity on this changing globe is a major challenge (Ricketts et al. 2004; Lavorel et al. 2007; Priess et al. 2007; Turner et al. 2007a,b). Human transformation of land cover and land use are the primary causes of biodiversity loss (Haines-Young 2009). As a consequence, continuous habitats are being divided into discontinuous patches, which affects population recruitment (Robinson et al. 1995; Smith & Hellmann 2002), survival (Harris 1984) and movement (Shirley 2006; Tucker et al. 2018) of terrestrial animal species (Suárez-Seoane et al. 2008; Tucker et al. 2018).

Gilan province is one of the most rapidly changing provinces in terms of land use (forest to agricultural land) in Iran (Nohegar et al. 2015). As a result of land-use change, urban growth and land degradation, the distributions of some terrestrial species have changed in recent years (Ashoori 2009). To conserve biodiversity at a provincial scale, it is...
necessary to understand how recent environmental changes may affect the distribution of species.

The common pheasant (*Phasianus colchicus*) is one of the most widespread ground-dwelling game birds in the Palearctic region, listed as Least Concern in the International Union for Conservation of Nature Red List (IUCN 2016). Several studies that have been conducted on the demography of and habitat selection by pheasants in Italy showed that male territories are preferentially placed along natural or spontaneous vegetation strips (wood edges, fences, hedgerows and tree rows) and in areas characterised by high habitat diversity (Meriggi et al. 1996; Nelli et al. 2012). The presence and abundance of populations are linked to the presence of suitable vegetation for the settlement of territorial males (Nelli et al. 2012). Hen density, however, seems to be more linked to suitable sites for nesting, because they choose to nest out of territories defended by males (Hill & Robertson 1988; Nelli et al. 2012). Baxter et al. (1996) showed that patches of smaller size that are characterised by long and irregular edges are more suitable habitats compared to larger patches with regular edges. However, the study by Nelli et al. (2012) showed that pheasants select small habitat patches but with more regular edges. Sage and Tucker (1998) found that nesting bird density was significantly lower in larger patches of short-rotation forestry, and highlighted the positive effect of ecotone on nesting pheasants (Nelli et al. 2012). Pheasants utilise marginal belts that supply them with food and protect them from predators and severe weather, due to the development of herbaceous and bushy cover (Nelli et al. 2012). A study by Shuai et al. (2007) revealed that vegetation cover, distance to roads and slope are important variables in habitat and nest site selection by common pheasant at Taihe Nature Reserve in China. In addition, Li et al. (2009) showed that topography, vegetation cover, distance to water sources and human presence are important variables in foraging habitats selection by common pheasants in Huanglong Mountains, China. Climatic variables, especially precipitation, also were recognised to affect the species’ nest survival (Geaumont et al. 2017).

The common pheasant is included in the list of Iran’s protected species (Ashoori 2009), because it faces many threats such as habitat destruction, pollution from pesticides and overhunting. The common pheasant occurs in deciduous forests, woodlands, coastal scrub, marshes and riverine forests from the Kaleibar Mountains in the north of East Azerbaijan to the valley of the Hari Rud near Sarakhs in north-eastern Khorasan-e Razavi (Scott et al. 1975). *Phasianus colchicus* has four subspecies in Iran – *P. c. colchicus*, *P. c. talischensis*, *P. c. persicus* and *P. c. principalis* – that can be distinguished from each other based on morphological characteristics (Kayvanfar & Aliabadian 2013; Kayvanfar et al. 2013, 2017). *Phasianus c. colchicus* occurs in Kalibar Mountains in North of East-Azerbaijan province, *P. c. talischensis* in Gilan province, *P. c. persicus* from west of Mazandaran province to Golestan province (Kayvanfar & Aliabadian 2013; Mahmoudi et al. 2016), and *P. c. principalis* in north-east Khorasan-e-Razavi province from Quchan County east to Sarakhs County (Kayvanfar & Aliabadian 2013; Kayvanfar et al. 2017). Despite this species being known in terms of morphology (Kayvanfar et al. 2013) and phylogeny (Kayvanfar et al. 2017), its habitat selection remains unknown in Iran; as a consequence, conservation planning of the species is hampered by this lack of information.

Our work is the first effort to build a robust habitat suitability model and explore the environmental drivers of common pheasant distribution in Iran. In the present study we examined the population from Gilan province, where the subspecies *P. c. talischensis* is present. It has been reported that the subspecies *talischensis* is very rare throughout its range (BirdLife International 2016) and has decreased in many parts of the province during recent years due to habitat destruction, land-use changes and over-hunting. Because of recent rapid changes of land use in Gilan province (Ashoori 2009; Nohegar et al. 2015) we hypothesised that anthropogenic factors such as roads and human-modified land use including agricultural lands and orchards are the most important variables in shaping the distribution of *P. c. talischensis* in Gilan province.

**Materials and methods**

**Study area**

Gilan province (36°34'N to 38°27'N, 48°53'E to 50°34'E) is located in the north of Iran and south-west of the Caspian Sea. It is the second smallest province in Iran, with an area of 14,042.3 km². Elevation ranges from 26 m below sea level to over 3000 m above sea level. The population of Gilan is 2,410,523, giving a population density of 171.7 inhabitants per square kilometre. The climate is humid subtropical, with up to 1850 mm annual precipitation (Molavi-Arabshahi et al. 2016). Much of the province was formerly covered in dense Hycranian forest with many tree genera such as Persian iron wood (*Parrotia persica*), Caspian honey

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locust (Gleditsia caspica), Caucasian wingnut (Pterocarya fraxinifolia) and Silk tree (Albizia julibrissin) surviving from the last ice age (Scharnweber & Rietschel Manthery 2007), but only a small portion of this ecoregion remains now. The main forms of land use include livestock rearing, rice farming, tea plantations and fruit farms (Eshaghpour et al. 2010; Ashoori & Abdoos 2013).

Species distribution data and explanatory variables

In order to obtain occurrence data from the entire distribution range of the species, field observations were carried out throughout the Gilan province (Figure 1) between 3 April and 5 May 2015. This is the best time of year to hear calls from male common pheasants, especially in the early morning (Ashoori 2009). Fieldwork was conducted from 05:30 until 07:30 every morning in all 16 counties in the province, and all potential sites for the presence of the species were surveyed. Unpublished reports and old distribution maps of the species in the Department of Environment were used to identify all potential sites for the presence of the common pheasant. To make sure we covered all potential sites, we searched 3–6 stations at each potential site. At least one observer was present at each station. To avoid duplicate recording of one individual the observer did not leave the station at sampling time and could only move at a distance of 100 to 150 m around their established location. At the end of sampling time, we registered coordinates of the site by global positioning system (GPS), if we heard a calling male common pheasant or saw a male or female of the species. Due to the topographic condition of the area, the stations within potential sites were selected between 1000 and 1500 m apart.

Ecogeographical variables including land cover, topography, and anthropogenic and bioclimatic variables (Table I) were used for modeling the distribution of common pheasant. These factors are known to influence the species’ distribution (Robertson et al. 1993; Robertson 1997; Ni et al. 2001; Bliss 2004; Leif 2005; Shuai et al. 2007; Li et al. 2009; Géaumont et al. 2017). Climatic variables were obtained from the WorldClim database (Hijmans et al. 2005). Common pheasants are mainly observed in forests, plantation forests, rangelands, agriculture and orchards (Ashoori 2009). These habitats provide food and shelter for the species in the study area (Ashoori 2009). Land cover data were obtained from the National Land Cover Map of the Forests, Range and Watershed Management Organization of Iran (FRWOI 2010). These data were derived from 30 m Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery for the conterminous Iran in 2010. The distance to human settlements (urban and rural areas) and distance to roads were included in the model because these anthropogenic variables had an influence on the distribution of birds in the study area (Ashoori 2009). The layer of human settlements was extracted from the National Land Cover Map of FRWOI (FRWOI 2010). Road data were downloaded from OpenStreetMap. All environmental variables were prepared using ArcGIS 9.3 (ESRI 2009).

Data analysis

In order to develop a habitat suitability model for the subspecies talischensis in Gilan, we used Maxent
software, version 3.3.3.k (Phillips et al. 2006). The Maximum entropy model (Maxent) is one of the universal Java-based learning tools in species distribution models based on the maximum-entropy approach (Phillips et al. 2006, 2017). By using presence data of species and environmental layers, Maxent calculates the probability of occurrence of a given species in the study area (Phillips et al. 2006). This approach has greater predictive power compared to other models such as GARP and BIOCLIM (Elith et al. 2006; Pearce & Boyce 2006), and produces robust models when the sample size is low (Hernández et al. 2006; Pearson et al. 2007).

We ran Maxent with maximum iterations of 500, a convergence threshold of 0.0001 and 10,000 background points. We randomly partitioned occurrence records of the species into a training set with 80% of the records and the test set with 20% of the records.

The performance of the model was assessed using the area under the curve (AUC) metric of the receiving operator characteristic (ROC) curve (Phillips et al. 2006). The AUC is commonly used as a measure of model performance (Fourcade et al. 2013; Kafash et al. 2016, 2018). Models with AUC > 0.75 are considered adequate and those with AUC > 0.90 are considered excellent (Elith 2000). We also obtained alternative estimates of variable importance for our Maxent models by conducting a jackknife test of variable importance (Phillips et al. 2006).

Results
Habitat suitability modeling using 11 ecogeographical variables and 122 occurrence points indicated that 22.5% of Gilan province is suitable for the subspecies talischensis. Given that the total area of the province is 1,404,230 hectares, the total potential suitable habitat for the subspecies talischensis in Gilan province is 315,990 hectares (Figure 2).

The overall predictive ability of the model (AUC = 0.906 for training and 0.842 for test data) showed high discrimination capacity in determining suitable and unsuitable habitats.

We found that agriculture and orchards, with 35% contribution, and plantation forests, with 24.4% contribution, were the most important variables in predicting the distribution of the common pheasant in Gilan province. Results showed that these two variables had a positive effect on the distribution of common pheasant. The probability of the presence of the species decreases with an increase in distance to agriculture and orchards and as well as distance to plantation forests (Table II).

Jackknife analysis
Results of the jackknife test of variable importance showed that the environmental variable with the highest gain, when used in isolation, is the presence of agriculture and orchards. The environmental variable that decreases the gain the most when it is omitted is the presence of plantation forests. This means that the variable ‘plantation forests’ has the most information that is not present in the other variables (Table III).

Discussion
Species distribution models are fundamental tools for conservation and management of rare and poorly
documented species (Williams et al. 2009; Yousefi et al. 2015). In addition, they help ecologists and conservation biologists to better understand the potential distribution of species and determine the most important environmental variables that shape their distribution. Despite the fact that *P. c. talischensis* has been described as a very rare species throughout its range (BirdLife International 2016), we obtained 122 distribution records of the subspecies and were able to build a robust distribution model for it in Gilan province.

Based on the Maxent model and the jackknife test of variable importance, distance to agriculture and orchards and distance to plantation forests were the most important variables in predicting the distribution of common pheasant in Gilan province. We concluded that anthropogenic variables are more important in predicting the distribution of the species than natural environmental variables. These variables (agriculture and orchards and plantation forests) are important because they provide food and shelter for the species. Agricultural lands have...
Table III. The results of the jackknife test of importance of variables. “Without variable” refers to when each variable is excluded in turn and a model created with the remaining variables; “with only variable” refers to when each model is constructed using only one variable.

| Predictive variable | Description | Without variable | With only variable |
|---------------------|-------------|------------------|--------------------|
| Topographic         | Slope: steepness | 1.116 | 0.0014 |
| Anthropogenic       | Roads: distance to roads | 1.08 | 0.0883 |
|                     | Human settlements: distance to urban and rural areas | 1.093 | 0.1783 |
| Land cover          | Forest: distance to forest with 5–25% canopy cover | 1.023 | 0.0258 |
|                     | Forest: distance to forest with 25–50% canopy cover | 1.093 | 0.0216 |
|                     | Forest: distance to forest with more than 50% canopy cover | 1.054 | 0.1388 |
|                     | Rangeland: distance to the nearest patch covered by grass or grassland with scattered crops or woody vegetation | 1.059 | 0.22445 |
|                     | Agriculture and orchards: distance to the nearest patch covered by irrigated farms and orchards | 1.011 | 0.4059 |
|                     | Plantation forests: distance to the nearest patch covered by plantation forests | 0.9046 | 0.2665 |
| Bioclimatic         | Precipitation seasonality (standard deviation/mean) | 1.114 | 0.2342 |
|                     | Maximum temperature of warmest month | 1.093 | 0.2913 |

been reported as an important habitat requirement for other game birds in Iran, such as the Asian houbara bustard (Chlamydotis macqueenii) (Yousefi et al. 2017a) and little bustard (Tetrax tetrax) (Yousefi et al. 2017b). Here we report on the importance of orchards and plantation forests as human-modified ecosystems in shaping the distribution of common pheasant in Iran.

We also found that the species prefers forests with canopy cover of 5–25% because these forests are largely covered by shrubs and bushes, which common pheasant use as a refuge. Li et al. (2009) showed that in Huanglong Mountains of China, common pheasant use habitats with less than 30% tree cover. However, habitats with more than 30% (30–50%) cover were occupied by brown-eared pheasant (Crossoptilon mantchuricum) (Li et al. 2009). Since the anti-predator behaviour of common pheasant is to hide (Hill & Robertson 1988; Robertson 1997; Li et al. 2009), the species avoids forests with canopy cover greater than 25% because it may not be possible for the species to hide in these forests due to the lack of shrubs and bushes (A. Ashoori pers. obs.). In addition, because in emergency situations the species chooses flight to avoid predators, lower tree density might facilitate take-off (Li et al. 2009). In conclusion, common pheasants need both forests and agricultural lands because agricultural lands provide food and forests provide shelter for the species.

Previous studies have found that topographic variables are important in species habitat selection (Shuai et al. 2007; Li et al. 2009), but in our study topography was not identified as an important predictor in species habitat selection. This may be a result of studying the species habitat selection at a different spatial scale. We studied the species’ habitat selection at a large spatial scale (Gilan province) compared to other studies, which assessed the species’ habitat selection in a relatively smaller area (Shuai et al. 2007; Li et al. 2009).

**Implications for conservation and future research**

Conservation of the common pheasant in a rapidly changing province in the north of Iran will be a challenging task. In Gilan, many suitable habitats located in hilly areas with a high density of common pheasants have been converted into orchards and tea plantations, while suitable habitats in the plains have been destroyed as a result of urban development and population growth, except in some private lands (Ashoori 2009). These changes have led to shifts of the species to higher altitudes in the province, and now they can be seen at altitudes of more than 1500 m above sea level. This was never observed in the past (Ashoori 2009). A similar pattern was reported for the common pheasant in Xiaoshennongjia Mountains, China (Wang et al. 2004). Deforestation and replanting on mountains in Xiaoshennongjia have led to a significant increase in the elevational distribution of the species (Wang et al. 2004). Now, in Xiaoshennongjia Mountains common pheasant is absent from low-lying areas and occurs at what appears to be an unusually high altitude (Wang et al. 2004).

We predict that as natural habitats decrease in Gilan province, more common pheasants will be forced to move into agricultural land and orchards. We suggest raising awareness among local landowners about the presence of common pheasants on their land. In particular, landowners should be made aware that their daily activities may put common pheasant nests and chicks at risk. We also encourage ecologically friendly farming practices for conservation of this species, for example...
reduced use of pesticides, and leaving rough vegetation around field edges that provides a source of insects and vegetable food in the breeding season. In addition, improving habitat quality (e.g. preserving shrub cover) would increase suitable habitats for the species.

Browsing and grazing can be serious threats to germination and may hamper height growth in trees (Nasiri et al. 2018). This may eventually lead to an empty forest floor (Goetsch et al. 2011). Therefore, limiting grazing in the area is critical for retaining the understory needed for many forest species (Gharehaghaji et al. 2012). The creation of a network of protected areas on private land and changes in land-use policy at the provincial level are essential for the conservation of the subspecies _talischenisis_ in Gilan province.

Our results show that human-induced land-cover changes may favour the species. As the extent of the natural habitat for the common pheasant in Gilan province is decreasing, the species is shifting into the agricultural land, orchards and plantation forests that are the dominant land-use types in Gilan province. Currently, it is unknown whether moving into a new habitat has any influence on the breeding success and survival rates of the common pheasant. Further studies should therefore be carried out in the area to compare the breeding success and survival rates of common pheasants in their natural habitat and in those habitats into which they have been forced to move.

We interpreted our results in terms of habitat suitability of the subspecies _talischenisis_, which can be reflective of species habitat suitability. Further studies on the other subspecies of the common pheasant in Iran could improve the knowledge of the habitat preferences of the species.

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**Disclosure statement**

No potential conflict of interest was reported by the authors.

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