Landscape Ecol (2015) 30:67–75
DOI 10.1007/s10980-014-0100-5

RESEARCH ARTICLE

The effects of road networks and habitat heterogeneity on the species richness of birds in Natura 2000 sites in Cyprus

Christos Mammides · Costas Kadis · Tim Coulson

Received: 11 March 2014 / Accepted: 7 October 2014 / Published online: 17 October 2014

Abstract The large European supra-national network of protected areas, known as Natura 2000, is considered to be the cornerstone of the European Union's efforts to conserve its biodiversity. The effective management of these areas requires a good understanding of how human-induced ecosystem change, evident in these sites, affects habitats and species of interest. In this study, we examine the factors that influence the presence of birds in thirty-eight Natura 2000 sites in Cyprus. Using structural equation modeling (SEM), we test the direct and indirect effects of human population density, road networks and hunting on the overall species richness of birds and the species richness of four additional bird categories: (1) forest and shrubland species, (2) farmland species, (3) wetland species and (4) species listed in the Annex I of the Birds Directive (2009/147/EC). Other potentially important factors such as size of the area, habitat diversity, percentage of the area covered by migratory corridors and mean altitude, are also incorporated into the analyses. Our results show that road networks have negative effects on four of the five bird categories tested while area and habitat diversity positively influence all categories. These findings have significant conservation implications for the management of the Natura 2000 sites in the EU.

Keywords Bird richness · Road density · Habitat diversity · Vegetation cover · Protected areas · Structural equation modeling

Electronic supplementary material The online version of this article (doi:10.1007/s10980-014-0100-5) contains supplementary material, which is available to authorized users.

C. Mammides (✉) · T. Coulson
Division of Biology and Centre for Population Biology, Faculty of Life Sciences, Imperial College, Silwood Park, Ascot, Berkshire SL5 7PY, UK
e-mail: cmammides@gmail.com

C. Mammides · C. Kadis
Nature Conservation Unit, Frederick University, P. O. Box 24729, 1303 Nicosia, Cyprus

C. Mammides
Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan 666303, China

T. Coulson
Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK

Introduction

The successful conservation of the European Union's biodiversity largely depends on the effective management of its supra-national network of protected areas known as Natura 2000 sites. Member States are responsible for designating and managing their own sites according to the provisions of the EU's Directives on the conservation of wild birds (2009/147/EU; formerly 79/409/EEC) and the conservation of natural habitats and wild fauna and flora (92/43/EEC) (Fairbrass and Jordan 2001, Mücher et al. 2009). The Birds Directive, among other requirements, mandates the designation of a network of special protection areas (SPA) with the aim of improving the conservation status of bird species of European concern (Donald et al. 2007). Similarly the habitats directive requires the designation of an analogous network, of sites of community importance (SCI), for the protection of habitat types and plant and animal species of community interest (Fairbrass and Jordan 2001). Together, these areas make the Natura 2000 network (Fairbrass and Jordan 2001). Thus far, 26,406 such sites have been designated in the EU covering 17.9 % of its total area (Tsiafouli et al. 2013).

The majority of these sites have been affected by numerous human activities, such as for example crop production, livestock grazing and hunting, (Tsiafouli et al. 2013) which impact biodiversity in complex ways, often making conservation efforts challenging. To be able to develop and implement effectively the management plans the EU requires it is important to study and understand how these activities affect the habitats and species of interest in those areas. The type and intensity of anthropogenic disturbance varies within the network. Tsiafouli et al. (2013) found that sites located in southern Europe are more likely to be affected by tourism, urbanization, hunting activities and transportation. In addition, their analysis revealed that, out of the 20 Member States they studied, Cyprus had the highest percentage of Natura 2000 sites (86 %) affected by activities related to transportation and communication, including roads and motorways. A similarly high percentage of sites were affected by hunting and fishing (Tsiafouli et al. 2013).

For the purposes of this paper we use data from Cyprus to analyze the possible direct and indirect effects of anthropogenic factors, particularly human population density, road networks and hunting on the presence of birds in Natura 2000 sites. We incorporated into our analyses other relevant factors that possibly have an influence on the species richness of birds, such as the size of the protected site, habitat diversity, percentage of area covered by vegetation and by bird migratory corridors, and mean altitude. We tested the effects of these variables on (i) overall bird richness recorded in the sites and (ii) species richness of birds listed in the Annex I of the Birds Directive. These are species considered to be vulnerable or rare, or species that require "special conservation measures" (Donald et al. 2007). In addition, to examine whether various bird guilds respond differently to these factors we tested the effects of the explanatory variables on three bird categories classified according to their habitat preferences, i.e. (1) forest and shrubland species, (2) farmland species (3) wetland species.

Methods and materials

Study area

Cyprus is the third largest island in the Mediterranean Sea, covering an area of 9,251 km^2 (Iezekiel et al. 2004). Its climate is characterized by dry summers and mild winters, with a mean annual precipitation of 480 mm (Iezekiel et al. 2004; Paralikidis et al. 2010). Cyprus is part of the Mediterranean Basin biodiversity hotspot (Myers et al. 2000) and hosts more than 1865 plant species and subspecies, 131 of which are endemic (Iezekiel et al. 2004). Its avifaunal diversity is also considered high as more than 370 species have been recorded so far; 31 % of them are known to have bred at least once on the island and two of them are endemic to Cyprus, making it one of the Endemic Bird Areas of the world (Stattersfield et al. 1998; Iezekiel et al. 2004). In its effort to protect its biodiversity, Cyprus has already designated 61 Natura 2000 sites covering a total area of 1,760 km^2 (EC 2011a). All sites are located in the southern part of the island since currently the Government of Cyprus does not exercise control in the northern part due to a military invasion by Turkey in 1974 and the illegal occupation of that area since then. For the purposes of this study we analyzed 38 of those 61 sites (all SCIs; Fig. 1) for which detailed data were available. About a third of the sites overlap fully or partially with SPAs. A full list of sites included in the analysis is provided in Supplementary Table 1.

Data Collection

One of the main data sources was the BioCyprus database (version Sep. 2010), prepared by the Environment Service of the Republic of Cyprus. The database is available online at the Central Data

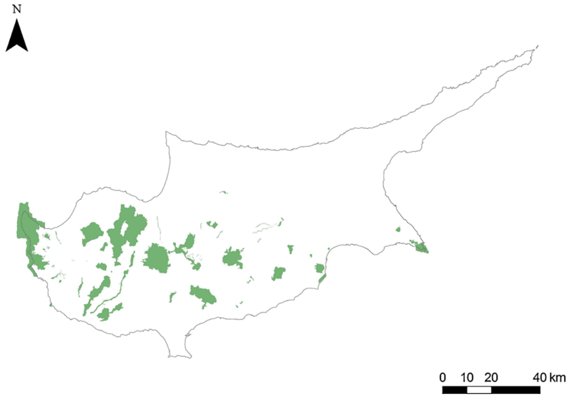

Fig. 1 Map of Cyprus showing the thirty-eight Natura 2000 sites used in our analyses

Repository of the European Environment Information and Observation Network (EIONET 2013). For each designated Natura 2000 site, the database includes a standard data form (SDF), compiled following the protocols developed by the European Commission (see EC 2011b for a full description), listing the abiotic and biotic characteristics of the area, and the threats the latter are facing from anthropogenic activities. The species lists in SDFs are compiled from bibliographic resources (listed in the form), and complemented by field visits whenever necessary to produce a complete list of the species of interest found in each area. For the purposes of our project we used the sites' SDFs to extract the number of bird species and species listed in the Annex I of the Birds Directive, the size of area of each site, its mean altitude, and the percentage of area covered by hunting reserves (i.e. areas in which hunting is prohibited).

Vegetation cover at each site was estimated using the CORINE Land Cover 2000 database (version 13), also made available online by the European Environment Agency (EEA 2014). CLC 2000 is a European-wide map depicting land cover in Europe, at the 25 ha level (Kallimanis and Koutsias 2013), using 44 different classifications grouped into five general categories: (1) artificial surfaces, (2) agricultural areas, (3) forest and semi-natural areas, (4) wetlands and (5) water bodies (Kallimanis and Koutsias 2013). Here we used category 3 as an index of vegetation cover in the Natura 2000 sites. Using ArcMap 9.2 (ESRI 2009), the total area covered by forests and semi-natural areas, excluding "open spaces with little or no vegetation" (Heymann et al. 1994) was calculated, which was then divided by the total area of each site to estimate the percentage of vegetation cover.

Human population densities were calculated using the census data of 2001 downloaded from the webpage of the Statistical Service of the Republic of Cyprus (Statistical Service 2014). Using ArcMap 9.2 all villages lying within the boundaries of each site were identified and their cumulative population size was divided by the site's area to obtain an estimate of its population density. Similarly, the density of road networks was estimated by calculating the total length of paved roads within each site, using the corresponding road map obtained after a request from the Department of Land and Surveys, and then dividing it by the site's area.

Habitat diversity was estimated using unpublished data provided by the Department of Forests, which has mapped all habitats found in the SCIs of the island using 166 categories. The Shannon–Wiener diversity index (Magurran 1988) was used to estimate habitat diversity as follows:

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i)$$

where S is the number of habitats, and p_i is the relative cover of each habitat calculated by dividing the cover of each habitat by the total cover in each site.

The percentage of area covered by migratory corridors was estimated using the map of the spatial distribution of the migratory flyways in the island, prepared and provided by the Game Fund of Cyprus. The total area covered by the corridors was divided by the area of the site to get an estimate of the percentage cover.

To test whether the explanatory variables chosen for this analysis had different effects on birds with different habitat preferences, species were grouped in the following categories using the classification in Tucker and Evans (1997): (1) Mediterranean forest, shrubland and rocky habitat species, (2) Farmland species, (3) Wetland species.

Model development and statistical analyses

A preliminary path model was developed illustrating how the above variables may be expected to influence the species richness of birds recorded at each of the thirty-eight sites of community importance (SCI) in

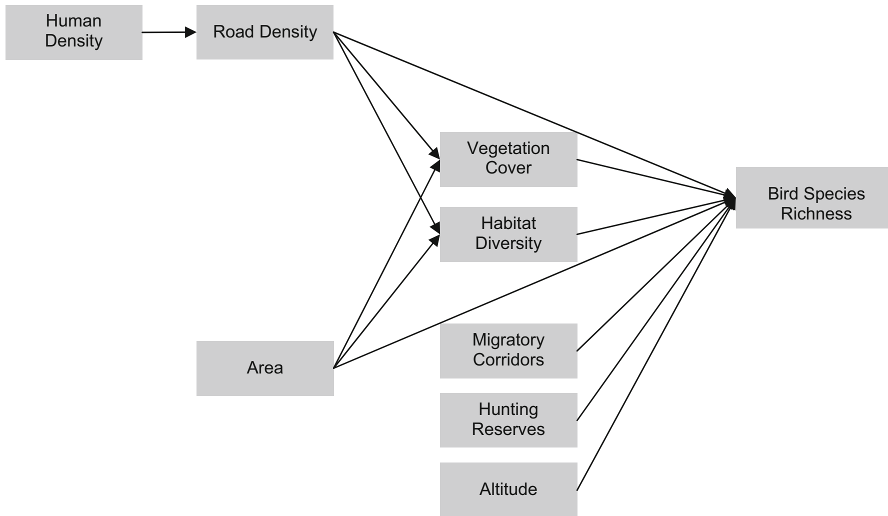

Fig. 2 Initial path model showing how the chosen explanatory variables might be influencing the species richness of birds in the Natura 2000 sites

Cyprus. The model was then presented to experts (Supplementary Table 2) from various organizations, working on biodiversity related issues in Cyprus, and was subsequently re-specified following their feedback.

Based on the resulting model (Fig. 2) it was hypothesized that human population density would have an indirect effect on bird species richness by influencing road density levels within each site, which themselves were thought to negatively directly affect bird communities. Road densities were also hypothesized to negatively affect the vegetation characteristics of the sites i.e. vegetation cover and habitat diversity, which were thought to have a positive effect on bird richness in protected sites. Area was thought to have a positive direct effect on habitat diversity, vegetation cover, and bird species richness. Lastly, it was hypothesized that mean altitude, percentage covered by hunting reserves (i.e. areas where hunting is not allowed) and migratory corridors would have a positive direct impact on bird richness (Fig. 2).

Analyses were conducted in AMOS 20.0, a statistical package developed by SPSS for structural equation modeling (SEM). Variables were tested for spatial autocorrelation using the Moran's I test in ArcMap 9.2 and log-transformed, when necessary, to achieve normality. Vegetation cover was the only variable normalized with a probit transformation due to its sigmoid distribution. To assess the goodness-of-fit for each model the Chi square test was used to check whether the model-implied covariance matrix differed significantly from the observed one, in which case the model was rejected, re-specified and retested (Grace 2006). To assess the goodness of fit of the final models, three further tests were used (RMSEA, NFI, CFI) following the suggestion of Schermelleh-Engel et al. (2003).

Results

A total of 248 species of birds were recorded in the 38 study sites, 94 of them being species listed in Annex I of the Birds Directive. Fifty four were forest and shrubland species, 84 farmland and 79 wetland ones. The average area of the study sites was 23 km^2. The minimum area was 0.05 km^2 and the maximum 182.57 km^2. The average density of paved roads was 0.36 km/km^2, ranging from zero to 1.40 km/km^2. Eleven sites had no hunting reserves at all while in seven hunting was prohibited in all areas. The average percentage covered by hunting reserves was 38 %. Table 1 shows the correlation matrix for all the independent variables included in the model, after transformed to achieve normality. Correlations were weak showing that colinearity between the predictors was very little.

Human population densities ranged from 1 to 221 $people/km^2$, with an average of 41.5 $people/km^2$. The average vegetation cover was 52 % ranging from 0 to 100, and the average habitat diversity was 1.18 ranging from 0 to 2.42. Mean altitude ranged from near sea level to 1,326 m (average 427 m). The average percentage of migratory corridor cover was 36 % with some areas fully covered by corridors and some others not covered at all.

Table 1 Pearson correlation coefficients (n = 38) for the eight independent variables used in our analyses

	Human density	Vegetation cover	Habitat diversity	Road density	Area	Altitude	Migratory corridors	Hunting reserves
Human density	–	−0.04	0.41*	0.20	0.40*	0.19	0.27	0.07
Vegetation cover	−0.04	–	−0.17	0.23	0.36*	0.45**	0.08	0.17
Habitat diversity	0.41*	−0.17	–	0.11	0.15	−0.12	0.35*	−0.03
Road density	0.20	0.23	0.11	–	0.34*	0.39*	0.31	0.12
Area	0.40*	0.36*	0.15	0.34*	–	0.33*	0.20	0.28
Altitude	0.19	0.45**	−0.12	0.39*	0.33*	–	0.12	0.09
Migratory corridors	0.27	0.08	0.35*	0.31	0.20	0.12	–	−0.04
Hunting reserves	0.07	0.17	−0.03	0.12	0.28	0.09	−0.04	–

Significance levels: * 0.05, ** 0.01

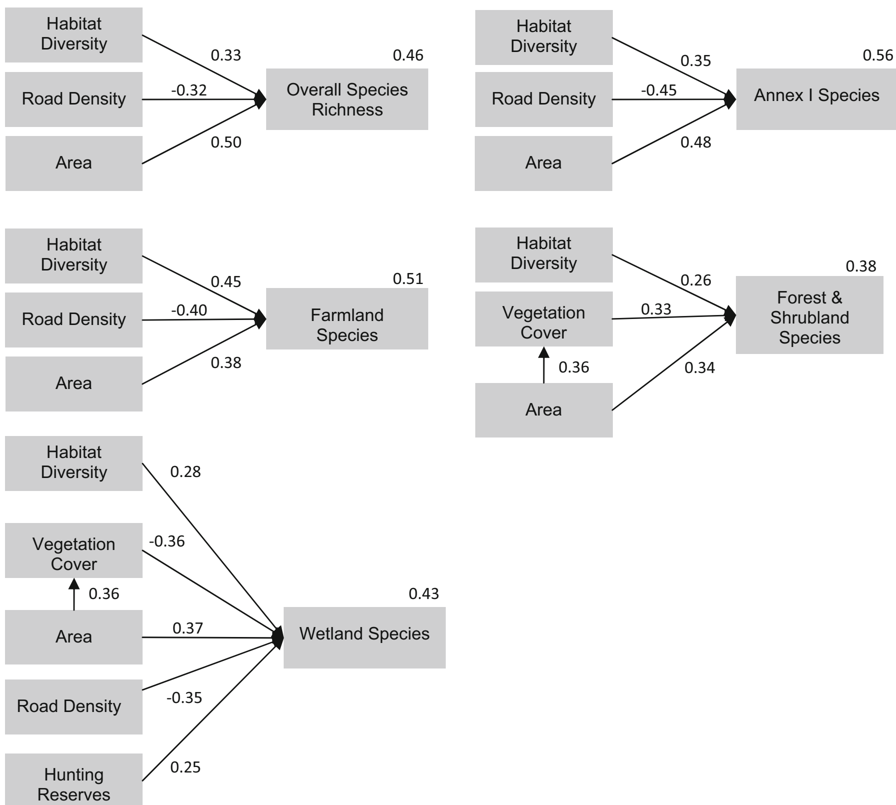

Fig. 3 The final path model for each bird category showing the factors affecting their species richness

SEM analyses

The resulting model did not fit the data well for any of the categories tested and therefore it was re-specified by the stepwise removal of non-significant variables, starting with the least significant in each bird category. The final parsimonious models are shown in Fig. 3. The R^2 values of the final models ranged from 0.38 (for forest and shrubland species) to 0.56 (for Annex I species; Table 2).

Bird categories

The overall bird species richness was positively influenced by habitat diversity (standardized path

Table 2 Goodness-of-fits tests and R^2 values for the five SEM models tested

	Chi square	R^2	RMSEA	NFI	CFI
Overall species richness	5.494 (df = 3, p = 0.139)	0.46	0.150	0.781	0.869
Annex I species	5.494 (df = 3, p = 0.139)	0.56	0.150	0.822	0.899
Farmland species	5.494 (df = 3, p = 0.139)	0.51	0.150	0.804	0.887
Forest & shrubland species	2.971 (df = 2, p = 0.226)	0.38	0.115	0.883	0.950
Wetlands species	11.751 (df = 9, p = 0.228)	0.43	0.091	0.689	0.879

Table 3 The resulting path coefficients (n = 38) for each relationship included in the five final models

	Overall species	Annex I species	Farmland species	Forest & shrubland species	Wetland species
Habitat diversity → Species Richness	0.33**	0.35***	0.45***	0.26*	0.28*
Area → Species Richness	0.50***	0.48***	0.38***	0.34*	0.37**
Road density → Species Richness	−0.32**	−0.45***	−0.40***	–	−0.35**
Vegetation cover → Species Richness	–	–	–	0.33*	−0.36**
Area → Vegetation Cover	–	–	–	0.36*	0.36*
Hunting reserves → Species Richness	–	–	–	–	0.25*

Significance levels: * 0.05, ** 0.01, *** 0.001

coefficient: 0.33; Table 3; Fig. 3) and the size of the area (0.50), and was negatively affected by road density (−0.32). These three variables consistently affected all bird categories tested, except in the case of forest and shrubland birds for which road density had no statistically significant impact. The size of the standardized path coefficients varied according to the category tested, but overall results showed that larger areas with higher habitat diversity were more likely to have more species, while areas with higher road density were likely to have fewer.

Compared to overall bird richness, the negative effect of road density on Annex I species was stronger (−0.45), whereas the positive affects of habitat diversity and area were similar (0.35 and 0.48 respectively). Farmland birds were most affected by habitat diversity (0.45) and least affected by the size of the area (0.38). Road density also had strong negative effects (−0.40). Forest and shrubland species richness were positively affected by the cover of forest and natural vegetation (0.33), a factor that only influenced this category and wetland birds (negatively in that case; −0.36). Habitat diversity and area had positive impacts on the forest and shrubland species (0.26 and 0.34 respectively). Area also had a positive indirect effect on the species by positively affecting vegetation cover (0.36). Thus the total cumulative effect of area was 0.46 (i.e. $0.33 \times 0.36 + 0.34$).

Wetland birds were the only bird categories for which the total percentage of area covered by hunting reserves had a significant positive effect (0.25). In other words, assuming all else being equal, sites with more areas prohibiting hunting were likely to have higher species richness. As in the rest of the models, habitat diversity and area had a strong direct positive effect (0.28 and 0.37 respectively). Area however in this case had also a negative indirect effect by positively influencing vegetation cover (0.36), which negatively affected wetland species richness (−0.36). The total cumulative effect of area in this case was 0.24 (i.e. $-0.36 \times 0.36 + 0.37$). Lastly, road density had a strong negative effect (−0.35).

Discussion

For developing effective conservation plans for protected areas it is important to have a good understanding of the factors that influence their biodiversity. Here we show how important information already available can be linked together, using an appropriate statistical tool, to extract meaningful conservation conclusions for that purpose. We advocate that analogous approaches can be used in other regions to extract equivalent information, which can be used to inform the management plans of those protected areas.

In the case of Cyprus, our quantified results showed that the size of the area is one of the most important determinants of species richness, concurring with the large literature on species–area relationships (SAR) and showing that larger areas are able to support more species (MacArthur and Wilson 1967; Blake and Karr 1987; Nilsson et al. 1988). Evidently, this important relationship needs to be taken into account when designing and managing protected areas, especially considering that often management authorities are under pressure to reduce the size of an area as much as possible due to socioeconomic reasons.

SAR models have been also used to examine the relationship between habitat diversity and species richness, and although in some cases it is difficult to elucidate, since habitat diversity may act synergistically with area (Rafe et al. 1985; Kallimanis et al. 2008), it is widely accepted that habitat heterogeneity typically has a positive effect (Boecklen 1986; Pino et al. 2000; Atauri and de Lucio 2001; Schindler et al. 2013). This was also found in our study showing that when managing Natura 2000 sites it is important to maintain their habitat diversity to be able conserve the bird species richness.

Interestingly, although in some cases the positive effect of habitat diversity is in essence a result of larger areas, since those areas are likely to host more habitats which can accommodate the ecological requirements of a more diverse range of species, in our case habitat diversity seems to be acting independently and it is not affected by the size of the areas as reported in many studies (Ricklefs and Lovette 1999; Kallimanis et al. 2008). This seemingly odd result is probably due the fact that the area of the SCIs examined in this study has been partly determined by the extent of the range of the habitats they were designated to protect. In other words, habitats with large ranges resulted in larger areas but lower habitat diversity, thus possibly cancelling out the positive effects of area.

The road network had a significant negative impact on the bird communities. Although it has been shown in the literature that the exact effects of roads are often area and species-specific, it is in generally accepted that road networks usually have a negative effect (Findlay and Houlahan 1997; Trombulak and Frissell 2000; Brotons and Herrando 2001; Benítez-López et al. 2010; Kociolek et al. 2011). Roads can result in among other things habitat degradation and fragmentation, higher noise disturbance and increased human access (Peris and Pescador 2004; Coffin 2007; Benítez-López et al. 2010; Kociolek et al. 2011; Selva et al. 2011). Their effects can be evident up to several kilometers from their location (Benítez-López et al. 2010).

While it is not possible to conclude from our type of analysis the exact mechanisms by which roads affect the species richness of birds in Natura 2000 sites, it is clear from our results that it is negative and needs to be addressed. Interestingly, the impact was strongest on Annex I species, which are birds considered to be of European importance, more vulnerable to disturbance and requiring extra conservation attention (Donald et al. 2007). Based on these results, we argue that to successfully conserve Annex I species in the EU it will be essential for the management authorities to research further the underlying mechanisms of this relationship and develop mitigation measures. In fact, road densities will possibly represent one of the main challenges to the conservation of species in Europe, which has been largely affected by this factor (Selva et al. 2011). In the recent decades road networks in the EU have increased noticeably, and in some countries have even doubled (Selva et al. 2011), with Natura 2000 sites in southern Europe affected the most (Tsiafouli et al. 2013).

Interestingly, forest and shrubland birds was the only category for which roads had no effect. Although the corresponding path coefficient was negative it was non-significant and thus removed from the model. The model for this group explains a relatively small percentage of its variance (R^2 0.38) showing that other important factors, not included in this analysis, are likely to be influencing their presence. As expected though, percentage of forest cover and natural areas was a significant factor for these species.

Forest cover had a negative effect on wetland species indicating that high vegetation cover may correlate negatively with habitat suitability for these species. Wetland birds were the only species that benefited significantly from larger cover of areas in which hunting is prohibited and as shown in other areas this bird guild is vulnerable to hunting (Fox and Madsen 1997; Jiguet et al. 2012). Considering that hunting in southern Europe is particularly intense (Tsiafouli et al. 2013), possibly exerting a strong pressure on bird species, it is important that this relationship is studied further in future studies. Lastly, as with the rest of the models, the R^2 value (0.43) indicates that other factors not included in the analysis might be affecting the presence of these species. The distribution and the size of the natural and artificial waterbodies for example within the protected areas is likely to be an important determinant of the presence of wetland species and needs to be considered in future analyses.

Acknowledgments We are thankful to experts from BirdLife Cyprus, Department of Forests, Game Fund and the Environment Service for providing useful feedback on the preliminary model. We are also thankful to Mick Crawley, Alex Kirschel and two anonymous reviewers for commenting on the results and providing additional suggestions. This project was funded by the Research Promotion Foundation of Cyprus, with co-funding from the European Union's Structural Funds (Protocol PENEK/Support/0308/42).

References

Atauri JA, de Lucio JV (2001) The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. Landscape Ecol 16:147–159

Benítez-López A, Alkemade R, Verweij PA (2010) The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biol Conserv 143:1307–1316

Blake JG, Karr JR (1987) Breeding birds of isolated woodlots: area and habitat relationships. Ecology 68:1724–1734

Boecklen WJ (1986) Effects of habitat heterogeneity on the species-area relationships of forest birds. J Biogeogr 13:59–68

Brotons L, Herrando S (2001) Reduced bird occurrence in pine forest fragments associated with road proximity in a Mediterranean agricultural area. Landsc Urban Plan 57:77–89

Coffin AW (2007) From roadkill to road ecology: a review of the ecological effects of roads. J Transp Geogr 15:396–406

Donald PF, Sanderson FJ, Burfield IJ, Bierman SM, Gregory RD, Waliczky Z (2007) International conservation policy delivers benefits for birds in Europe. Science 317:810–813

EC (2011a) Natura 2000 Barometer, European Commission. http://ec.europa.eu/environment/nature/natura2000/barometer/index_en.htm#newstat. Accessed Jan 2011

EC (2011b) Commission Implementing Decision of 11 July 2011 concerning a site information format for Natura 2000 sites (notified under document C (2011) 4892). http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011D0484. Accessed Oct 2014

EEA (2014) CORINE Land Cover 2000 (CLC 2000). http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-clc2000-seamless-vector-database. Accessed Oct 2014

EIONET (2013) Eionet Central Data Repository. http://cdr.eionet.europa.eu/cy/eu/n2000/envtkl3sg. Accessed Oct 2014

ESRI (2009) ArcMap 9.2. ESRI (Environmental Systems Resource Institute), Redlands

Fairbrass J, Jordan A (2001) Protecting biodiversity in the European Union: national barriers and European opportunities? J Eur Public Policy 8:499–518

Findlay CS, Houlahan J (1997) Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conserv Biol 11:1000–1009

Fox A, Madsen J (1997) Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implications for refuge design. J Appl Ecol 34:1–13

Grace JB (2006) Structural equation modeling and natural systems. Cambridge University Press, Cambridge

Heymann YC, Steenmans G, Croisille, Bossard M (1994) Corine land cover project-technical guide. European Commission, Directorate General Environment. Nuclear safety and civil protection, ECSC-EEC-EAEC, Brussels-Luxembourg

Iezekiel S, Makris C, Antoniou A (2004) Important bird areas of European Union importance in Cyprus. BirdLife Cyprus, Nicosia

Jiguet F, Godet L, Devictor V (2012) Hunting and the fate of French breeding waterbirds. Bird Stud 59:474–482

Kallimanis AS, Koutsias N (2013) Geographical patterns of Corine land cover diversity across Europe: the effect of grain size and thematic resolution. Prog Phys Geogr 37:161–177

Kallimanis AS, Mazaris AD, Tzanopoulos J, Halley JM, Pantis JD, Sgardelis SP (2008) How does habitat diversity affect the species–area relationship? Glob Ecol Biogeogr 17:532–538

Kociolek A, Clevenger A, St Clair C, Proppe D (2011) Effects of road networks on bird populations. Conserv Biol 25:241–249

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton

Magurran AE (1988) Ecological diversity and its measurement. Princeton University Press, Princeton

Mücher CA, Hennekens SM, Bunce RGH, Schaminée JHJ, Schaepman ME (2009) Modelling the spatial distribution of Natura 2000 habitats across Europe. Landsc Urban Plan 92:148–159

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Nilsson SG, Bengtsson J, As S (1988) Habitat diversity or area per se? Species richness of woody plants, carabid beetles and land snails on islands. J Anim Ecol 57:685–704

Paralikidis N, Papageorgiou N, Tsiompanoudis A, Konstantinou L, Christakis T (2010) Foods of hunter-killed *Black francolins* (*Francolinus francolinus)* in Cyprus. Eur J Wildl Res 56:89–93

Peris S, Pescador M (2004) Effects of traffic noise on paserine populations in Mediterranean wooded pastures. Appl Acoust 65:357–366

Pino J, Rodà F, Ribas J, Pons X (2000) Landscape structure and bird species richness: implications for conservation in rural areas between natural parks. Landsc Urban Plan 49:35–48

Rafe R, Usher M, Jefferson R (1985) Birds on reserves: the influence of area and habitat on species richness. J Appl Ecol 22:327–335

Ricklefs RE, Lovette IJ (1999) The roles of island area per se and habitat diversity in the species–area relationships of four Lesser Antillean faunal groups. J Anim Ecol 68:1142–1160

Schermelleh-Engel K, Moosbrugger H, Müller H (2003) Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. Methods Psychol Res 8:23–74

Schindler S, von Wehrden H, Poirazidis K, Wrbka T, Kati V (2013) Multiscale performance of landscape metrics as indicators of species richness of plants, insects and vertebrates. Link Landsc Struct Biodivers 31:41–48

Selva N, Kreft S, Kati V, Schluck M, Jonsson B-G, Mihok B, Okarma H, Ibisch PL (2011) Roadless and low-traffic areas as conservation targets in Europe. Environ Manag 48:865–877

Statistical Service (2014) Population Census 2001. http://www.cystat.gov.cy/mof/cystat/statistics.nsf/index_en/index_en?OpenDocument. Accessed Oct 2014

Stattersfield AJ, Crosby MJ, Long AJ, Wege DC (1998) Endemic bird areas of the World: priorities for biodiversity conservation. BirdLife Conservation Series no. 7. BirdLife International, Cambridge

Trombulak SC, Frissell CA (2000) Review of ecological effects of roads on terrestrial and aquatic communities. Conserv Biol 14:18–30

Tsiafouli MA, Apostolopoulou E, Mazaris AD, Kallimanis AS, Drakou EG, Pantis JD (2013). Human activities in Natura 2000 sites: a highly diversified conservation network. Environ Manag. doi: 10.1007/s00267-013-0036-6-9

Tucker GM, Evans MI (1997) Habitats for birds in Europe: a conservation strategy for the wider environment. BirdLife International, Cambridge