Acta Oecologica 71 (2016) 14–21

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Original article

Do unpaved, low-traffic roads affect bird communities?

Christos Mammides [a, b, *], Constantinos Kounnamas [a], Eben Goodale [c], Costas Kadis [a]

[a] Nature Conservation Unit, Frederick University, P.O. Box 24729, 1303, Nicosia, Cyprus
[b] Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla, Yunnan Province, 666303, China
[c] College of Forestry, Guangxi University, Nanning, Guangxi Province, 530005, China

ARTICLE INFO

Article history:
Received 30 November 2015
Received in revised form
9 January 2016
Accepted 10 January 2016
Available online 18 January 2016

Keywords:
Forest management
Bird richness
Unpaved road networks
Habitat heterogeneity
Protected areas

ABSTRACT

Unpaved, low traffic roads are often assumed to have minimal effects on biodiversity. To explore this assertion, we sampled the bird communities in fifteen randomly selected sites in Pafos Forest, Cyprus and used multiple regression to quantify the effects of such roads on the total species richness. Moreover, we classified birds according to their migratory status and their global population trends, and tested each category separately. Besides the total length of unpaved roads, we also tested: a. the site's habitat diversity, b. the coefficient of variation in habitat (patch) size, c. the distance to the nearest agricultural field, and d. the human population size of the nearest village. We measured our variables at six different distances from the bird point-count locations. We found a strong negative relationship between the total bird richness and the total length of unpaved roads. The human population size of the nearest village also had a negative effect. Habitat diversity was positively related to species richness. When the categories were tested, we found that the passage migrants were influenced more by the road network while resident breeders were influenced by habitat diversity. Species with increasing and stable populations were only marginally affected by the variables tested, but the effect of road networks on species with decreasing populations was large. We conclude that unpaved and sporadically used roads can have detrimental effects on the bird communities, especially on vulnerable species. We propose that actions are taken to limit the extent of road networks within protected areas, especially in sites designated for their rich avifauna, such as Pafos Forest, where several of the affected species are species of European and global importance.

1. Introduction

Protected areas are considered vital for the conservation of species worldwide (Gaston et al., 2008). A key aspect to the successful management of protected areas is understanding how human-induced habitat changes affect the biodiversity of a region. The type and level of anthropogenic activities within protected areas depend on a range of factors, such as the geographic location of the site and the socio-economic factors that operate there. For example, in the European Union, sites located in southern European countries are more likely to be affected by hunting (Tsiafouli et al., 2013). Yet, inarguably one of the most common and widespread activity, evident in almost all areas, is the establishment and the use of road networks (Trombulak and Frissell, 2000; Husby and Husby, 2014). For that reason, along with the fact that new road networks are being planned and constructed on a continuing basis (Laurance and Balmford, 2013), assessing the effects of road networks on species is of high conservation importance.

We know from the plethora of the studies available in the field of road ecology that the effects of roads vary according to the area and species studied (Husby and Husby, 2014; Mammides et al., 2015). Morelli et al. (2014), in the review of ninety-two studies published over the last four decades, showed that roads and other transportation related structures can have positive effects on certain species in some cases. For example, Helldin and Seiler (2003) found that in south-central Sweden roadsides were associated with higher habitat heterogeneity, which benefited forest birds. On the other hand, many studies have shown that roads often have significant negative effects on many species, by resulting for example in habitat loss and fragmentation or increased disturbance due to higher presence of humans (Forman and Alexander, 1998; Fahrig and Rytwinski, 2009; Kociolek et al., 2011). The effects can be direct, such as increased mortality due to collisions with

* Corresponding author. Nature Conservation Unit, Frederick University, P.O. Box 24729, 1303, Nicosia, Cyprus.
E-mail address: cmammides@xtbg.ac.cn (C. Mammides).

http://dx.doi.org/10.1016/j.actao.2016.01.004
1146-609X/

vehicles, or indirect, such as behavioral changes resulting from higher levels of noise and pollution (Brotons and Herrando, 2001; Benítez-López et al., 2010). The mechanisms by which roads affect bird communities can be multileveled and complex. For example, they can affect the reproductive cycles of birds by reducing nest success, and at the same time reduce the fitness of individuals by interfering with foraging calls and prey detection (reviewed in Kociolek et al., 2011). The impacts of roads may also have different time scales, ranging from mortality caused during road construction, to long-term community changes due to the alteration of the physical and the chemical environment (Trombulak and Frissell, 2000).

The exact effects of roads also depend on the extent and the type of the road network within an area (Laurance and Balmford, 2013; Robson and Blouin-Demers, 2013). So far, most of the studies on the effects of roads have focused on high-traffic paved roads (Šálek et al., 2010), presumably because their effects can be potentially more adverse (Laurance and Balmford, 2013). Apart from resulting in habitat loss, highly-used paved roads are also likely to affect species in additional ways, as they make an area accessible to a higher number of people, they result in higher levels of pollution and may be more difficult to be crossed by animals (Robson and Blouin-Demers, 2013), thus affecting their movement to a larger extent. Unpaved roads on the other hand, especially low-traffic roads, are unlikely to affect species in these ways, so they are often assumed to have weaker effects, caused mostly by habitat loss and increased edge effects (Ortega and Capen, 2002; Laurance et al., 2004).

In this study we test and quantify the extent to which low-traffic unpaved road networks affect the bird communities in Pafos Forest, Cyprus, using multiple linear regression modeling. In conjunction to the road networks we also include in our models habitat heterogeneity, which has been shown to have a strong positive effect on the bird communities in protected areas in Cyprus (Mammides et al., 2015). Furthermore, we examine the effects of human presence (based on the population size of the nearest village) and distance to the nearest agricultural field, along with a number of other landscape metrics that have been shown to have a significant effect on birds in similar ecosystems (Schindler et al., 2013). Following the results of previous studies (Hargis et al., 1998; Morelli et al., 2013; Schindler et al., 2013), which have shown that the performance of landscape metrics depends on the scale measured, we assess the effects of our predictor variables at six different distances from the bird point-count locations: 100 m, 250 m, 500 m, 750 m, 1 km and 1.25 km. We chose Pafos Forest as the study area because it is a nature reserve of high ornithological importance, which has been designated as a Special Protection Area (SPA), i.e. a Natura 2000 site (Hadjipanayiotou, 2012) and has a particularly dense network of unpaved roads. Many of these roads, which are maintained on a regular basis, are closed to the public and are mostly used by the Department of Forests for management purposes, such as for access in case of fire and for patrolling.

2. Material and methods

2.1. Study area

Pafos Forest is located in the northwestern part of Cyprus (Fig. 1), an island of high ornithological importance (Iezekiel et al., 2004). More than 370 species of birds have been recorded in Cyprus so far, of which about 85% are non-resident species (Iezekiel et al., 2004). Pafos Forest covers an area of 602.68 km^2 (Hadjipanayiotou, 2012). Its altitude ranges from near sea level to 1352 m, receiving an annual mean precipitation of 1060 mm (Hadjipanayiotou, 2012). The site is covered mostly by *Pinus brutia* forest, with its understory consisting mainly of thermo-Mediterranean sclerophyllous vegetation such as *Quercus alnifolia*, *Arbutus andrachne* and *Cistus* spp. (Hadjipanayiotou, 2012).

The high ecological significance of the forest stems from the fact that it is an important area for birds (Iezekiel et al., 2004), supporting populations of 22 species listed in the Annex I of the European Union's Birds Directive, including the four endemic species and subspecies of Cyprus (*Oenanthe cypriaca*, *Sylvia melanothorax*, *Certhia brachydactyla dorothea* and *Parus ater cypriotes*; Hadjipanayiotou, 2012). Additionally, the forest is one of the most important areas in Cyprus for nesting raptors such as *Hieraaetus fasciatus* and *Accipiter gentilis*.

According to Hellicar et al. (2014), a major threat to Pafos Forest's biodiversity is habitat degradation, resulting in fragmentation, caused by the establishment of firebreaks and the dense network of roads. The majority of the roads are low-traffic unpaved roads built by the authorities for better accessing and managing the forest. For the purposes of this study we sampled twenty sites, all located next to existing roads. Due to the forest's steep topography it was not feasible to select sites at varying distances from the road. The sites were spread throughout the west-central part of the forest (Fig. 1). Areas in the very far north and the east were avoided for logistic purposes since, due to the forest's large size and topography, it was not practical to also cover those within the amount of time available. We selected and surveyed twenty sites randomly using Hawth's Analysis Tools (Beyer, 2004) in ArcMap (Version 9.3.1), by first dividing the chosen part of the forest into 2 km $\times$ 2 km grid cells to ensure adequate distance between the sites and to avoid spatial autocorrelation. Note, however, that during the analysis we had to disregard five of the sites because they were located less than 1.25 km from the forest's boundary; data on the road network, habitat diversity, and the rest of the landscape metrics were only available for areas within the forest boundaries and consequently these sites had to be excluded due to missing information. Our results are therefore based on fifteen sites. Results from analyses that included more sites, but with smaller radii around them, were qualitatively similar, but explained less of the variation.

2.2. Bird censuses

We conducted bird censuses, along the roadside, during the spring migration of 2012, between early March to mid-May, using 10-min point counts (Bibby et al., 1992). We decided to sample birds during the migratory season, as many species in the forest (including several of the high conservation importance) are migratory (Iezekiel et al., 2004). We visited each site six times to ensure adequate sampling. We carried out all surveys between sunrise and 10:00 AM. We rotated the order by which we surveyed the sites to make sure that no site was constantly sampled in early or late morning. During the surveys we identified and recorded all species seen or heard within a distance of 100 m from the sampling point. To account for species that were possibly missed during the surveys, we estimated species richness at each site using the first-order Jackknife richness estimator (Magurran, 1998), using the *specpool* function in "vegan" package in R (R Core Team, 2015). We used the species migratory status list provided to us by BirdLife Cyprus, to classify birds into "Resident Breeders" and "Passage Migrants". We also classified species according to their global population trends, using the corresponding data from BirdLife International, which are available online (BirdLife International, 2014).

2.3. Sites characteristics

Using ArcMap, we established six nested circular buffer zones of