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Drove roads: Keystone structures that promote ant diversity in Mediterranean forest landscapes

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ABSTRACT

Drove roads are the traditional corridors used by pastoralists for seasonal movements of livestock (transhumance). They cover a considerable land area in Mediterranean countries and, although they are an obvious source of landscape diversity, their influence on the diversity and composition of animal assemblages has not been documented. Ant communities were studied on four active drove roads, two in forests (submediterranean and conifer) and two in open environments (croplands and rangelands). They were compared with the respective matrix communities and their contribution to local species richness was evaluated. The effects were heavily dependent on the open or closed nature of the matrix. In forest environments, drove roads increased ant species richness at the local scale, acting as clear keystone structures. Their species richness and functional diversity were highest on the fine scale, species composition was different, and a slight edge effect in the matrix was detected. In contrast, drove roads had little or even a negative effect in open environment locations. We conclude that drove roads have a high conservation value for ants in Mediterranean forest environments, in addition to their importance as reservoirs of plant biodiversity and generators of ecological goods and services.

1. Introduction

Drove roads, also known as stock routes, are one of the most characteristic components of traditional landscapes in Mediterranean countries (Ruiz and Ruiz, 1986; Mangas Navas, 1992; Merino García and Alier Gándaras, 2004). Active drove roads stand out in the landscape as well-defined strips up to 100 m in width with a savannah-like grassland appearance, in some cases running for several hundred kilometres. They are reserved for and ecologically modeled by transhumance, a traditional type of pastoralism consisting on the seasonal movement of livestock between summer and winter pastures. In Spain, drove roads cover nearly 1% of the country's land area, with a total length of about 125,000 km (Mangas Navas, 1992; Merino García and Alier Gándaras, 2004). Due to their grid-like distribution, most of the country's land area is in contact with or near a drove road (Azcárate et al., 2012). Drove roads are at least several centuries old, and may have originally been based on the migratory routes of wild ungulates (Manzano and Casas, 2010). Because of their enormous area, long-term persistence, impact on the landscape structure and capacity to host herbivore migrations, drove roads can have played a major ecological role in the Mediterranean Basin. The current crisis in extensive grazing has led to the abandonment of transhumance and grazing uses of drove roads (Ruiz and Ruiz, 1986; Ruiz, 2001), causing a loss of their differentiation from the surrounding ecological matrix. Their influence on populations and communities may thus disappear before they are identified and studied.

The few published ecological studies of drove roads have focused on their effects on plant communities. Drove roads have traditionally been regarded as a good example of ecological corridors for plant species (review in Bunce et al., 2006), although no experimental evidence supported this view until Manzano and Malo (2006) detected epizoochorous seed dispersal over distances of up to 400 km. More recently, the effects of drove roads on landscape patterns, species composition and functional diversity of plant communities have been measured (Azcárate et al., 2012), showing that drove roads are a source of spatial heterogeneity and a reservoir for many plant species in non- or moderately-grazed habitats.

Drove roads could also have a noticeable effect on the diversity and composition of animal assemblages. Active drove roads maintain patches of open grassland in non-grazed environments such as forests, and hence increase spatial heterogeneity. Spatial heterogeneity and diversity of several animal species groups are often

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(but not always) correlated (Duelli, 1997; Atauri and de Lucio, 2001; Szczepko et al., 2012). It has been argued that each animal species group depends on a specific structural aspect of the vegetation whose presence or quality can be detected at a certain spatial scale (Tews et al., 2004). At that scale, biodiversity is favoured by the occurrence of “keystone structures”, characterized by their ability to provide resources, shelter or nesting sites to that species group. Examples of keystone structures at different spatial scales are tree cavities in forests (for insects, birds and mammals), trees in African savannas (for arboreal rodents, ungulates, raptors and other species groups) and temporary wetlands in agricultural fields (for carabid beetles) (Tews et al., 2004; Remm and Lohmus, 2011). If a key structure affects several species groups, or groups with a strong influence on ecosystem functioning, then its conservation is of crucial importance. Drove roads might then function as keystone structures by favouring rich groups of terrestrial species with relevant roles on ecosystem functioning, such as ants.

Ants are considered to be a focal group for the monitoring of terrestrial ecosystems (Underwood and Fisher, 2006; Crist, 2009). This is not surprising, given their ability to stockpile a considerable amount of primary and secondary production, interact with several organisms and act as ecosystem engineers (Folgarait, 1998; MacMahon et al., 2000; Crist, 2009). Literature shows that ants respond strongly to land management (Bestelmeyer and Wiens, 1996; Chen et al., 2011), and are sensitive to different levels of grazing (Read and Andersen, 2000; Boulton et al., 2005; Azcarate and Peco, 2012). Moreover, ants are widespread, moderately diverse and easy to sample (Alonso and Agosti, 2000; Andersen et al., 2004). Their role as indicators has improved with the development of the concept of functional groups to classify ants within species assemblages, as first proposed in Australia (Andersen, 1995), and then extended worldwide (Brown, 2000). More recently, the role of ants in ecosystem functioning has been studied by measuring their functional diversity (Bihn et al., 2010; Silva and Brandao, 2010) although this approach has still been little addressed, in contrast to other taxa.

The present study evaluates the role of drove roads as keystone structures. Specifically, our work analyzes the effects of drove roads on ant assemblages by measuring species richness, functional diversity and species composition on active drove roads and in the surrounding landscape matrices. Four sites were chosen in different traditional Mediterranean landscapes along a gradient of forest growth. We expected the effects to be dependent on the location, increasing with structural differences between the drove road and the ecological matrix.

2. Materials and methods

2.1. Study area

The study was done on the siliceous southern pediment of the Guadarrama Range (Madrid Autonomous Region, Central Spain, Fig. 1; Table 1). The four selected locations along a forest gradient were representative of the major landscape units in the area (Coniferous forest, Sub-Mediterranean forest, Rangeland and Cropland). All locations included a drove road with moderate grazing intensity and no sign of land disturbance by non-livestock agents. In all cases, the ecological matrix was well preserved and managed in a similar way to traditional land uses for at least the last 30 years.

2.2. Sampling design

In each location, we selected an approx. 2 ha drove road fragment of about 300 m–400 m long by 40–50 m wide. Three habitat

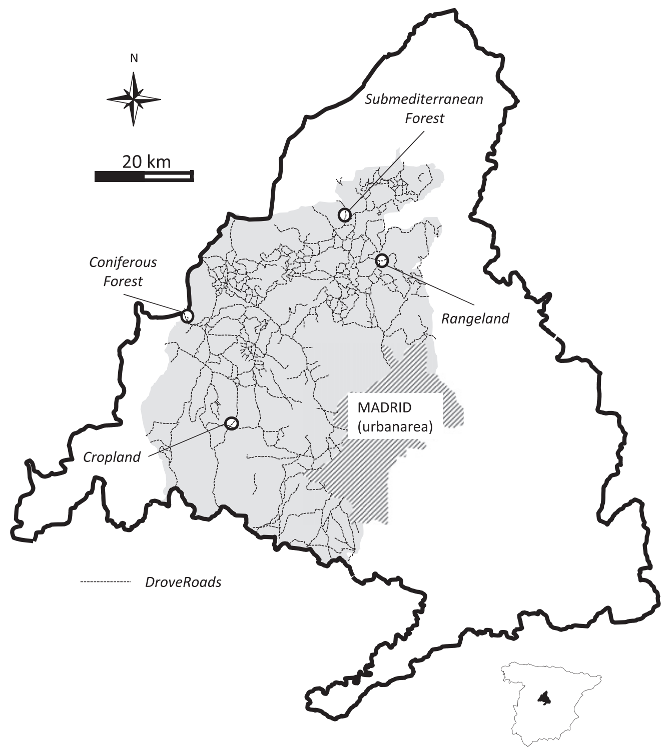

Fig. 1. Study area in the Madrid Autonomous Region (Spain). The map shows the study locations and the drove road network. The drove road distribution is taken from the official map in www.viaspecuariasdemadrid.org.

types were distinguished in each location: the drove road itself, the adjacent matrix and the distant matrix. The adjacent matrix was located between the edge of the drove road and a distance of 75 m, while the distant matrix was more than 200 m from the edge. Both types of matrices were structurally similar, but were considered separately to take into account potential edge effects in the adjacent matrix. The slope and aspect of the three habitat types (drove road, adjacent matrix and distant matrix) were similar in each location.

Sampling was performed in July 2010. Fifteen sampling units were randomly arranged in each location, five per habitat type. All sampling units of the same habitat type were included in the 2 ha area, set at least 25 m apart. One sampling unit consisted of (1) a set of three pitfall traps (2 cm diameter $\times$ 5 cm deep) forming a triangle with vertexes 1 m apart (for ground-dwelling species) and (2) a set of three baits in different trees less than 10 m apart (for arboreal species). The pitfall traps were filled with a mixture of 70% ethanol and 30% mono-ethylene glycol, and left in the field for 5 days. The bait, a combination of 1 cm^3 of honey and 1 cm^3 of tuna in oil, was placed at a height of 1.5 m on the tree trunk, then checked after 30 min. We recorded all ant species detected within 1 m of the bait in a 2-min observation. Each sampling unit was characterized by the complete list of species detected using both methods.

2.3. Distributional status of the ant species

In order to ascertain whether the species potentially benefited by the drove roads are either uncommon or widespread, we checked their distribution status in the Iberian Peninsula, using the range maps available in www.hormigas.org. To take into account that these maps could be biased by several factors (geographic distribution of myrmecologists, detectability of the different species), and could underestimate the distribution range of many