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Original investigation

Long-term assessment of roe deer reintroductions in North-East Spain: A case of success

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ABSTRACT

Worldwide species relocations are increasingly becoming an important part of species recovery programmes and ecosystem restoration initiatives. Monitoring reintroduced populations after release, in addition to understanding which factors affect translocations, is fundamental to understand the reintroduction process and to maximize the success of future interventions. By using boosted regression trees we evaluated the contribution of roe deer *Capreolus capreolus* reintroductions (1971–2008) to the current distribution of this species in Catalonia (Spain), and a partial least square regression approach was used to evaluate the influence of some variables as key for the roe deer reintroduction success. Our results show that roe deer currently occupies 85% of Catalonia territory, which represents an almost six-fold increase since the beginning of the 90s. Proximity to the nearest reintroduction nuclei was identified as one of the main drivers positively associated to the current distribution of roe deer in Catalonia, whereas the number of years after the first reintroductions and the number of animals released were important to the success of the reintroductions. We recommend the reintroduction of roe deer to release sites that contain large and suitable patches of habitat and that are sufficiently close to allow population continuity.
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Introduction

Species relocations (both reintroductions and translocations) are described as the deliberate release of individuals to the wild to establish new viable populations in their former habitats, to reinforce existing ones or to introduce individuals outside their original range (Seddon, 2010; IUCN/SSC, 2013; Houde et al., 2015). Worldwide species relocations are increasingly becoming an important part of species recovery programmes and ecosystem restoration initiatives (Armstrong and Seddon, 2008) as a response to the ongoing habitat fragmentation and destruction (Seddon et al., 2014). One of the main targets for species relocations is to restock game populations for commercial and conservation purposes (Fischer and Lindenmayer, 2000; Cruz et al., 2014; Torres et al., 2015).

Nevertheless, evaluating the success of reintroductions is difficult since it is dependent on a variety and complexity of factors, which include the number of animals initially released, age and sex composition of the founder population, habitat suitability of the reintroduction sites, the genetic structure/variability of the source population but also on the general public acceptance, among others (Griffith et al., 1989; Fischer and Lindenmayer, 2000; Lawrence and Kaye, 2011). Fischer and Lindenmayer (2000), in their assessment of published results from relocations of various taxa all over the world, showed that 30 (26%) out of 116 reintroductions were classified as successful, 31 (27%) as failures, while the fate of 55 (47%) translocations was unknown at the stage of publication. These results stress that translocations are often carried out in an unsuitable way and not prudently monitored. As a consequence, the success of reintroduction programs is generally low. But still, authors are more likely to publish their results if the outcome of the programme is successful, meaning that the majority of those initiatives may be

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overestimated (Fisher and Lindenmayer, 2000). Additionally, post-release monitoring programs are often abandoned after an initial short-term follow-up of the population and most results end up in grey literature (*e.g.*, technical reports), consequently useful information to aid future translocations is lost (Griffith et al., 1989). Thus, monitoring the reintroduced populations after their release, and specifically understand how several factors affect translocations, is vital to shed light upon the success of the reintroductions and will maximize the success of future interventions. As many authors pointed out, long term monitoring of the release individuals should be a chief component of any translocation project (Fischer and Lindenmayer, 2000; IUCN/SSC, 2013).

Roe deer *Capreolus capreolus* is considered a forest dwelling species that has successfully colonised the agricultural landscapes of Europe during the last 50 years (Apollonio et al., 2010). This story of success has been driven not only by the rural abandonment, but also by this mammal's ability to adapt its foraging patterns (Abbas et al., 2013), digestive plasticity (Serrano et al., 2012) and body reserves (Hewison et al., 2009) to more fragmented forest and cultivated crop landscapes. Roe deer is a valuable game species (Apollonio et al., 2010) with ca. 25,000 roe deer hunted in Spain every year (http://www.magrama.gob.es/es/). The increasing demand of hunting in recently colonized areas of the Iberian Peninsula (Portugal, Spain and Andorra) motivated the development of several reintroduction programmes (López-Martín et al., 2009; Cruz et al., 2014; Torres et al., 2015). However, other reasons such as the wolf conservation in Portugal (Carvalho et al., 2008; Cruz et al., 2014), or the species re-establishment (*e.g.*, hunting, increase local biodiversity, restoration of ecosystem functioning) (López-Martín et al., 2009) have also favoured the implementation of roe deer reintroduction plans.

With the aim to restore the native ungulate community and the possibility of a valuable trophy for hunting, a roe deer reintroduction plan was started in Catalonia, North-eastern Spain in the 90s. Although some individuals were previously released in areas where remaining population still existed, in the Pyrenees (Royo et al., 2007), in the latest release the geographical area chosen was the low mountain chains along the Mediterranean coast. In this area, the species has been absent since the 18th-19th century, mainly due to forest fragmentation and degradation and most probably to unsustainable hunting (Rosell and Carretero, 1998). The roe deer reintroductions in Catalonia offer an excellent long-term case-study opportunity to use past translocations to assess the array of factors that have been implicated in determining this project's success or failure. Taking advantage of 37 years of reintroductions (1971–2008), we explored the role of habitat structure, topography, hydrographic network, vegetation productivity and human activities on roe deer reintroduction success in Catalonia in order to develop guidelines to further roe deer reintroduction plans. We specifically intended to answer the following questions: i) which is the contribution of reintroductions to the current distribution of roe deer in Catalonia? and ii) which variables are key for the roe deer reintroduction success?

Material and methods

Study area

The Autonomous Community of Catalonia, NE Spain, is one of the most densely populated areas in Europe (average of 235 hab/km^2) and encompasses an area of 32,114 km^2 (41°29′N, 1°28′E; Fig. 1). Geographically it is divided in three areas: i) the Alpine and Subalpine Region of the Pyrenees, ii) the Catalan Mediterranean System – a region parallel to the Mediterranean coast elevations and planes with elevations altering with flat areas, and 3) the Catalan Central Depression – a structural unit which forms the eastern sector of the Valley of the Ebro river. In the Mediterranean area, summers are dry and hot (maximum temperature is around 26–31 °C). It snows frequently in the Pyrenees, and it occasionally snows at lower altitudes, even alongside the coast. Spring and autumn are typically the rainiest seasons, except for the Pyrenean valleys, where summer is typically stormy. The inland part of Catalonia is hotter and drier in summer. Temperature may reach 35 °C, some days even 40 °C. Fog is not uncommon in valleys and plains; it can be especially persistent, with freezing drizzle episodes and sub-zero temperatures during winter (record of −36 °C), along the Segre and in other river valleys. Rivers are small and run to the Mediterranean coast. Most landscape is occupied by forest (70% area), although is highly fragmented by other uses (*e.g.*, agriculture, urban, industrial). The 30% of Catalonia has some nature protection figure and included in the European Nature 2000 Network.

Roe deer reintroductions

From 1971 to 2008, 542 (239 males and 304 females) roe deer were released in Catalonia in 13 different areas (Table 1, Fig. 1). First releasing (1971–1989) events (46 roe deer) were in areas where the species lived and following the IUCN terminology they should have been considered as a population reinforcement or restocking (IUCN/SSC, 2013). During the last period (1993–2008) releasing events were in areas where roe deer was absent and consequently they were reintroductions. They were released in natural parks, mostly along the mountainous areas along the Mediterranean coast. The majority of roe deer came from France, the natural population nearest to Catalonia. During the first years, some animals (n = 26) came from Central Spain and during the last years, a few animals (n = 21) came from Catalonian Pyrenees. However, due to logistic and sanitarian reasons it was recommend that the animals would come from some reserves in France (Aquitania and the Landes region). Animals were captured and after sex and age selection they were transported in individual box cages. After 24 h roe deer were released directly in the release sites. The release sites were chosen according to the general roe deer environmental requirements (forested areas) and some nature protection (natural park or Nature 2000 site). In order to evaluate the adaptation of the released animals, some were fitted with VHF collars and their movements and survival tracked during the first year, in three reintroduction areas (Rosell and Carretero, 1998; López-Martín et al., 2009). These results show a low mortality rate during the first year (16.7%: range 5–31.1%), the mean probability of survival (365 days) was S = 0.78 (SE: 0.05), the mean dispersal distance was 4.5 km, and the maximal distance recorded was 18 km from the releasing point (López-Martín et al., 2009). Reproduction was also detected during the first year in the three areas.

Roe deer distribution

From terrestrial mammal atlas (Palomo and Gisbert, 2002; Palomo et al., 2007), roe deer distribution in Catalonia was represented as 10 km UTM grid during three periods (Fig. 2) but accurate locations of roe deer were achieved from three different sources during two years (2013–2014):

1) Traffic police reports where roe deer were involved in car damage;
2) Hunting data collected by game rangers;
3) Volunteer collaboration—during these two years game management service published a webpage where roe deer sightings could be registered.

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