The success of species reintroductions: a case study of red deer in Portugal two decades after reintroductio

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**ABSTRACT**
Reintroduction programs are important tools in the recovery or establishment of animal populations, but post-release monitoring, essential to evaluate their success, generally lacks in most projects. During the 1990s, a red deer (Cervus elaphus) reintroduction program took place in central Portugal. Almost two decades after the reintroduction, this study aimed to establish the current state of red deer populations. Density estimates were obtained through pellet group counts coupled with distance sampling using 61 linear transects. The results showed that red deer densities are of 3.10 ind./100 ha (95% confidence interval: 1.6–5.9) and this species is widely distributed throughout the area. Due to increase in numbers and range since the beginning of the reintroduction, this program can be considered a case of success; however, future monitoring programs should continue to be developed.

**Introduction**

Reintroductions are important tools in conservation programs, allowing community restoring initiatives and species recovery projects (Armstrong & Seddon 2008). Generally, the success of reintroduction programs is low (Beck et al. 1994) but as successful reintroductions are more likely to be published, the evaluation of the success of these programs can be biased (Fisher & Lindenmayer 2000). In this context, monitoring populations after their release, as well as assessing ecological relations with the environment (Torres et al. 2016), is vital to shed light into the outcome of the reintroduction. As in other European countries, Portugal has experienced an increase in numbers and distribution of wild ungulates over the last decades (Vingada et al. 2010), as is the case of red deer (Cervus elaphus) (Apollonio et al. 2010). During the 1990s, several reintroduction programs occurred throughout Portugal and one of the most iconic happened in central Portugal (Lousã mountains), where this species has disappeared due mostly to hunting pressure and habitat fragmentation and destruction (Fonseca et al. 2007). The releases took place between 1995 and 1999 and a total of 96 individuals (25 males, 56 females, and 15 fawns) were released in central area of Lousã mountains (Table 1) (Fonseca et al. 2007). These animals were originally from other areas in south Portugal, namely the hunting states of Vila Viçosa and Herdade da Contenda. The project aimed to increase and restore the herbivore biodiversity of the region but it also had hunting purposes (Vingada et al. 2010). In order to evaluate the success of the above-mentioned releases, as well as to provide valuable data for management plans, we used an indirect method (pellet group counting) coupled with distance sampling (Valente et al. 2014; Torres et al. 2015), to estimate the current density and distribution of red deer populations in Lousã mountains, two decades after their reintroduction.

**Materials and methods**

**Study area**

Lousã mountains (40°3′N, 8°15′W) are located in Coimbra district, in the centre of Portugal (Figure 1), and are characterized by a Mediterranean climate. The terrain is constituted by deep valleys and steep slopes with an altitudinal range from 300 to 1200 m (Ferreira et al. 1996). The other ungulate species present are the roe deer (Capreolus capreolus) and wild boar (Sus scrofa). Red deer hunting is a common practice throughout Lousã mountains and can occur all the year round (Fonseca et al. 2007). The vegetation is varied and characterized by large plantations of coniferous trees (e.g., Scots pine Pinus sylvestris, Maritime pine Pinus pinaster, Austrian pine Pinus nigra, Douglas fir Pseudotsuga menziesii and cypress Cupressus lusitanica) and some oak Quercus sp., sweet chestnut Castanea sativa, Portugal laurel Prunus lusitanica). The scrublands are present in almost 50% of the area and are dominated by heathers Erica spp., Calluna vulgaris, and Ulex spp. (Alves et al. 2013).
Field work

From March 2013 to June 2014, pellet groups of red deer were counted in sampling plots placed along a total of 61 transects randomly distributed in a total of 92,053 ha (ha), each with 1000 m of length. To maximize spatial coverage and mitigate sampling dependence, plots consisted of 100 m long of effective sampling, spaced 200 m (inside the transect but without survey) along the line, which accounted for 400 m of effort in each 1000 m transect. A portable Global Positioning System, a compass, and rope were used to ensure an accurate prospection, 1 m from each side of the line. In addition to the number of pellet groups, the perpendicular distance from the centre of each pellet group to the transect line was recorded as well as other variables: (i) size of the pellet group (small: 6–10 pellets, medium: 10–40 pellets, large: >40 pellets); (ii) habitat (open – with vegetation <0.5 m vs. closed habitat – with vegetation >0.5 m); and iii) dispersion of the pellet groups (scattered – when pellets are dispersed – or aggregated – when pellets are found together). Pellet groups with less than 6 individual pellets were not considered (Marques et al. 2001). For density estimation we used distance sampling, which implies the modulation of a detection function that is used to estimate the detection probability. A histogram is then built, which constitutes the main basis to density and abundance estimates. This methodology requires two conversion factors – the pellet group disappearance rate and the production rate – to convert the density of pellet groups into the density of animals (see Valente et al. 2014 for details). The pellet group disappearance rate used was of 581 ± 55 days, obtained for red deer in the same region (Alves et al. 2013), while the production rate used, of 25 pellets a day, was based on literature (Mayle 1996). Both Conventional Distance Sampling and Multiple Covariate Distance Sampling were tested in Distance 6.0 (Thomas et al. 2010). Data were right-truncated by 5%, to reduce impact of outliers (Buckland et al. 2001; Thomas et al. 2010). The best model was chosen based on the lowest value for the Akaike Information Criterion (AIC) and the chi-square ($\chi^2$) test (Thomas et al. 2010).

Results

A total of 24,400 m sampling effort was performed, with 248 pellet groups being counted. The estimated density was 3.1 ind./100 ha, with a 95% confidence interval (CI) of 1.6–5.9, which represents an average abundance estimated at 2856 individuals (Table 2). Results obtained for the study area (92,053 ha) suggest a better fitting of a hazard-rate model, with a cosine expansion series (AIC = 2007.80; $\chi^2 = 18.60$; df = 17.00; $p = 0.35$). None of the three covariates tested had influence in the detection function, so the selected model only considered distance as a factor (Table 3).

Since no pellet groups were detected in a significant extent of our study area, we focused on the smallest

### Table 1. Red deer reintroductions in Lousã mountains (date of release, number of males, females and fawns).

| Date         | Males | Females | Fawns | Total |
|--------------|-------|---------|-------|-------|
| March 1995   | 2     | 2       | 4     | 4     |
| March 1995   | 1     |         |       | 1     |
| August 1995  | 6     | 15      | 22    | 33    |
| September 1995 | 8  | 9       | 6     | 23    |
| December 1995 | 17 | 36      | 1 (♂) | 54    |
| Total 1995   | 34    | 63      | 28    | 125   |
| February 1996| 2     | 2 (♀)   | 1     | 5     |
| December 1996| 4     | 3       |       | 7     |
| Total 1997   | 4     | 7       |       | 14    |
| July 1997    | 3     | 6       | 2     | 11    |
| August 1997  | 3     | 11      | 2     | 16    |
| March 1999   | 1     | 4       | 5     | 10    |
| Total 1999   | 1     | 4       | 5     | 10    |
| Total        | 25    | 56      | 15    | 96    |

Source: Adapted from Fonseca et al. (2007).

Figure 1. Study area location. (a) Map of continental Portugal highlighting the full study area. (b) Full study area in light gray (total sampling area) and distribution area of red deer in dark grey.
portion of the original sampling area, where red deer pellet groups were found, for now onwards called red deer distribution area (59,914 ha) (Figure 1b). This area was calculated using the outer transects, where red deer pellet groups were found as the limits, which considered a total of 37 transects, comprising a sampling effort of 14,800 m. The estimated density was 5.2 ind./100 ha, with a 95% CI of 2.8 to 9.7, representing an estimated abundance, on average, of 3115 individuals (Table 2).

Results suggest a better fitting of a hazard-rate model, with a cosine expansion series (AIC = 2007.80; χ² = 18.60; df = 17.00; p = 0.35), while none of the three covariates tested seemed to have a greater influence in the detection function, and hence, the selected models considered only distance as a factor (Table 3).

Discussion

Our results show that, since the reintroduction programs, during the 1990s, red deer population have been increasing, both in area and in number in Lousã mountains, which can function as an indicator of success of this reintroduction process. The overall density estimated for the study area (92,053 ha) was lower than in previous studies, but if we consider the density estimated for the distribution area (59,914 ha) it is quite similar (5.20 ind./100 ha in 15,000 ha, Fonseca et al. (2009); 5.37 ind./100 ha in 2500 ha, Alves et al. (2013)). However, as the methodologies used was different, caution is needed. As previously mentioned, density is estimated by dividing the number of pellet groups by the total effort length. Consequently, when adding transects with no pellet groups, the overall density will decrease, as the effort length increases. Since one of the purposes of this study was to determine the species distribution, the covered area needed to be extensive and explorative. Everything considered, the population seems to have stabilized in numbers over the last years, while their distribution area has increased toward northeast.

The detection probability estimated (31.6%) for the best model seemed to be lower than expected (Figure 2), which did not accurately reflect the sampling effort. This may have induced the abundance estimate to be somewhat higher than what may happen in reality, since the software compensates a low detection probability by assuming that an amount of pellets was not seen by the observer. Consequently, this can cause an increase in the abundance estimate, mainly based on an assumption that may not be accurate.

The pellet group disappearance rate was specific for the species and for the study area (Alves et al. 2013), so lower bias is expected however, since disappearance days can vary among habitats, the use of a site-specific value for each dominant habitat in each place, over the mean value, should be assessed in

![Figure 2](image_url)
future works. Furthermore, differences in disappearance rate among seasons must also be considered when treating data (Torres et al. 2013). Future studies should aim to estimate the production rate, considering the one used was from the U.K., as there is no value available for the Iberian Peninsula or for other regions where environmental conditions are more similar. This is particularly important since climatic conditions influence the food present in deer habitats and consequently feeding habits which has a clear role in production rate (Mitchell et al. 1985; Mayle et al. 1996; Marques et al. 2001). In fact, we are aware of this bias, as the used value did not have a variance or standard error associated, meaning the results obtained did not took into account rate variations. The coefficient of variation (%) value was higher than the expected, but this can occur in areas where population density is not high (Smart et al. 2004), such as in our study area. Several other studies regarding deer density have also recorded wide confidence intervals range, mainly where densities are smaller (Acevedo et al. 2010; Marques et al. 2001; Acevedo et al. 2008). Our results show that the red deer reintroduction project in Lousã mountains was a success, as population increased in numbers and expanded into new territories. Appropriate management policies should benefit from the information generated from these studies, and should achieve a balance between the different interests involved, with a comprehensive understanding of the population dynamics. Considering the ecological and social potential of red deer, future monitoring programs should continue to be developed, to account for possible threats, as well as to identify and minimize possible conflict situations.

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References
Acevedo P, Ferreres J, Jaroso R, Durán M, Escudero MA, Marco J, Gortázar C. 2010. Estimating roe deer abundance from pellet group counts in Spain: an assessment of methods suitable for Mediterranean woodlands. Ecol Indic. 10: 1226–1230.
Acevedo P, Ruiz-Fons F, Vicente J, Reyes-García AR, Alzaga V, Gortázar C. 2008. Estimating red deer abundance in a wide range of management situations in Mediterranean habitats. J. Zool. 276: 37–47.
Alves J, Silva AA, Soares AMVM, Fonseca C. 2013. Pellet group count methods to estimate red deer densities: precision, potential accuracy and efficiency. Mam Biol. 78: 134–141.
Apollonio M, Andersen R, Putman R. 2010. European ungulates and their management in the 21st century. Cambridge: Cambridge University Press.
Armstrong DP, Seddon PJ. 2008. Directions in reintroduction biology. Trends Ecol Evol. 23:20–25.
Beck BB, Rapaport LG, Price MRS, Wilson AC. 1994. Reintroduction of captive-born animals. In: Olney PJ, Mace GM, Feistner ATC, editors. Creative conservation: interactive management of wild and captive animals. London: Chapman and Hall; p. 265–286.
Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. 2001. Introduction to distance sampling. London (UK): Oxford University Press.
Ferreira AJ, Vingada JV, Cancela JH, Keating AL, Sousa JP, Soares M, Fonseca C, Faria M, Soares AMVM. 1996. Proceedings of the international union of game biologists, The game and the man: use of space and time by introduced red deer (Cervus elaphus L.). In XXIIth Congress of the International Union of Game Biologists, Sofia, Bulgaria.
Fisher J, Lindenmayer DB. 2000. An assessment of the published results of animal relocations. Biol Conserv. 96:1–11.
Fonseca C, Alves J, Silva A 2007. Plano global de gestão para a população de veados da Serra da Lousã – [Global management plan for red deer population for Serra da Lousã]. Ministry of agriculture, Rural development and Fishing/University of Aveiro.
Fonseca C, Alves J, Silva A 2009. Plano global de gestão para a população de veados da Serra da Lousã – Plano de exploração 2009/2010. [Global management plan for red deer population for Serra da Lousã – Exploratory plan 2009/2010]. Ministry of agriculture, Rural development and Fishing/University of Aveiro.
Marques FFC, Buckland ST, Goffin D, Dixon CE, Borchers DL, Mayle BA, Peace AJ. 2001. Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. J Appl Ecol. 38:349–363.
Mayle BA. 1996. Progress in predictive management of deer populations in British woodland lands. For Ecol Manag. 88:187–198.
Mayle BA, Doney J, Lazarus G, Peace AJ, Smith DE. 1996. Fallow deer (Dama dama L.) defecation rate and its use
in determining population size. Supplemento Alle Ricerche Di Biologia Della Selvaggina. 25:63–78.
Mitchell BD, Rowe JJ, Ratcliffe PR, Hinge M. 1985. Defecation frequency in roe deer (Capreolus capreolus) in relation to the accumulation rates of faecal deposits. J Zool. 207:1–7.
Smart JCR, Ward Al, White PCL. 2004. Monitoring woodland deer populations in the UK: an imprecise science. Mamm Rev. 34:99–114.
Thomas L, Buckland ST, Rexstad EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. J Appl Ecol. 47:5–14.
Torres RT, Carvalho J, Fonseca C, Serrano E, López-Martin JM. 2016. Long term assessment of roe deer reintroductions in North East Spain: A case of success. Mam Biol. 81:415–422.

Torres RT, Santos JP, Fonseca C. 2013. Persistence of roe (Capreolus capreolus) and red (Cervus elaphus) deer pellet-groups in a Mediterranean mosaic landscape. Mamm Biol. 9:7–18.
Torres RT, Valente AM, Marques TA, Fonseca C. 2015. Estimating red deer abundance using the pellet-based distance sampling method. J For Sci. 61:422–430.
Valente AM, Fonseca C, Marques TA, Santos JP, Rodrigues R, Torres RT. 2014. Living on the edge: Roe deer (Capreolus capreolus) density in the margins of its geographical range. Plos One. 9:e88459.
Vingada J, Fonseca C, Cancela J, Ferreira J, Eira C. 2010. Ungulates and their management in Portugal. European ungulates and their management in the 21st century. Cambridge: Cambridge University Press; p. 392–418.