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Study of survival, dispersal and home range of autumn-released red-legged partridges (*Alectoris rufa*)

M.E. ALONSO, J.A. PÉREZ, V.R. GAUDIOSO, C. DIÉZ AND R. PRIETO

Animal Production II Department, Veterinary Faculty of León, Campus de Vegazana, León, Spain

Abstract 1. On a private property with a stable population of wild red-legged partridge (*Alectoris rufa*) and an appropriate habitat for the survival of the species, reinforcement repopulations were carried out in the months of October and November for two consecutive years using 5- to 6-month-old birds reared on a commercial game farm.

2. Of the 36 released birds, none was still alive by the following spring's breeding period. Mean survival time was 9·4 d in the first year and 7·6 d in the second year.

3. Seventy-two per cent of mortality was attributable to predation, 11% to hunting and 17% to doubtful causes of death, accidents and starvation.

4. Post-release mean dispersion was 377·8 m in the first year and 526·3 m in the second. Mean home range was 7·1 ha in the first year and 5·4 ha in the second.

5. The production systems and handling practices of commercial game farms may have modified some anti-predator ethological patterns and strategies, which might make it more difficult for the birds to adapt and integrate into the wild, resulting in reduced survival due to premature mortality.

INTRODUCTION

In Spain the red-legged partridge is the most appreciated of the small hunted species, and some of the hunting areas are world famous. However, from 1986, a serious decrease in the wild populations of this species has occurred (Redondo, 1993) in practically all parts of Spain. The decline is due to numerous causes, but in particular to major changes in their natural habitats. This decrease is due more to declines in large land areas where populations were never very dense, rather than decreases in small areas, where it is better protected by the diversity of its habitat, and where important populations are still present (Nadal, 1992). This phenomenon also affects other natural populations of partridges across the world (Aebischer and Potts, 1994).

Because of the economical and biological interest of the red-legged partridge there are attempts to break this trend by releasing large numbers of birds reared on game farms. In Spain, about 4 million birds are released into the wild every year, aimed both at increasing numbers for the hunt and also to reinforce natural populations by trying to increase the reproductive success of the species (Coll, 1991).

However, production systems and handling techniques on game farms are highly technical and intensive, producing changes in behaviour that are not characteristic of wild partridges. In addition, the imprinting process that the birds undergo causes long-term physiological and ethological modifications that consequently result in serious problems of adaptation and integration in the wild (Lucio, 1992; Gaudioso *et al.*, 2002).

The most common repopulation method in Spain involves the release in summer of 2- to 4-month-old red-legged partridge poults. This follows the recommendations of Leranoz and Castien (1989) after a complex study carried out in the Navarra region of Spain. Furthermore, Capelo and Castro Pereira (1996) stated that repopulations were more successful if carried out in summer using 2-month-old poults. However, recent studies (Pérez *et al.*, 2004) showed that summer repopulations were unsuccessful in producing a long-term increase in reproductive partridge numbers because none of the summer release birds survived to the following reproductive (spring) season.

The objectives of this study were to evaluate the capacity of game farm reared birds to adapt

Correspondence to: Marta Elena Alonso de la Varga, Dpto. Producción Animal II, Facultad de Veterinaria, Campus de Vegazana, 24071, Universidad de León, León, España. E-mail: dp2mav@unileon.es
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and to survive in a natural environment, and to determine the most frequent causes of mortality. Our long-term goals were to better understand the eco-ethological factors that determine adaptation of released game farm red-legged partridges to the wild, the management of released red-legged partridge populations and how to conduct more successful repopulations in the future.

MATERIAL AND METHODS

Study and animals

The study was carried out on 308 ha located in the Valladolid region of Castilla and León in Spain, an area that traditionally has been able to sustain partridge populations, with a crop habitat suitable for these birds and other game species such as rabbits and hares. The present wild partridge density is 65 birds per 100 ha, and the wild population is growing every year. In previous years, replanting on the property resulted in a diversity of plant species that provide shelter and food, including arboreal species (22·9% of the study area), such as *Pinus* spp. and *Cupressus sempervirens*; and bushy plants (37·2%), such as *Citissus* spp., *Crataegus* spp. and *Rubus* spp. The study area also included some cultivated lands (37%) with sunflower (*Helianthus annuus*), lucerne (*Medicago sativa*) and barley (*Hordeum distichon*).

To increase the reproductive success of game species, there were a number of drinking troughs and field troughs with cereal seeds (barley and wheat). Minimal control of predators was carried out, foxes in February and ravens in May, following the legal Spanish provisions.

Thirty-six 5- to 6-month-old red-legged partridges from a commercial game farm, subject to health and genetic checks, were released during two consecutive autumns. Each year 18 birds were used, 9 males and 9 females.

Procedures

The releases in both years occurred on one day of two consecutive weeks between late October and mid-November. Three birds were released at each of three different release points with similar environmental characteristics. Three points were used to avoid bird concentration at one location, which would act as a focus of attraction for predators (Church *et al*., 1984) and to study the effects of habitat on repopulation and survival.

Birds were directly released using cages ($40 \times 30 \times 30\ cm^3$) with a wooden base covered with a wire mesh in a triangle form that allowed the birds to see the environment. All the birds were transported in individual cages and at 10:00 h on the day they arrived in the study area they were equipped with radio transmitter collars, were placed in the cages and remained there for 5 min before their exit was permitted, in order to minimise manipulation stress. This direct release method was used because the use of acclimatising cages did not improve the results (Pérez *et al*., 2004).

Radio-tracking localisation

All the birds were equipped with Biotrack© radio transmitter collars (Biotrack Ltd, Wareham, Dorset, UK, http://biotrack.co.uk), with a weight of 9·8 g and an autonomous operating life of 11 months. On the right leg of each bird was placed a metallic numbered ring. After release, individual birds were tracked once per day at the same time from Monday to Friday, using a receiving unit (Yaesu©—http://yaesu.com) with a directional antenna (Gortázar *et al*., 1997). Each bird's daily location was scored on a land scale map. When inactivity or unusual movements were detected a search was conducted until the bird was sighted or there were appreciable changes in the reception intensity, in order to check if it was alive.

Mortality

When a partridge was found dead, a photograph was taken and the cause of death determined. Mortalities were assigned to one of the following groups:

Air predation (1): Cadaver with fleshed bones and feathers plucked cleanly with the quill attached.

Terrestrial predation (cause 2): mainly feathers remaining, with bites instead of having been plucked, and almost always with bite signs on the antenna of the radio transmitter. The only other part of the animal remaining was the caecum of the large intestine.

Doubtful death (3): When it was not possible to attribute death to one of the other causes, such as starvation, illness or accident.

Human hunts (4): Collar radio transmitter with clear signs of human hunting activity (presence of pellets) or necklace recovered from legal hunters.

Where possible, the cadaver was picked up and a formal necropsy was carried out to examine body condition, plumage state, presence of food in the crop and gizzard, and evidence of disease.

Data analysis

The Ranges V© computer program was used to calculate bird dispersion after release (Kenward and Hodder, 1996). The home range that each animal needed to carry out vital activities was calculated, as defined by the minimum convex polygon that included 95% of the localisations of each bird (excluding the release point).

The data were analysed by one-way ANOVA (Dixon, 1983) in order to assess the significance of differences between release points using the computer program SPSs© (version 10.0) for Windows©. The Newman–Keuls test (Dixon, 1983) was chosen for *post hoc* comparison of means. Differences with $P < 0{\cdot}05$ were considered significant.

RESULTS

There were no differences between release points for the survival values ($F_{(2,65)} = 2{\cdot}174$; $P = 0{\cdot}122$). The radio tracking carried out on all the birds allowed us to calculate that total mean survival duration following release was 8·5 d: 7·6 d for the first year and 9·4 d for the second. There were no significant differences in survival data between sexes and years ($F_{(3,32)} = 0{\cdot}142$; $P = 0{\cdot}93$). Mean female survival for the first year was 8·6 d (mean male survival 10·2 d) and 7·8 d in the second (males 7·6 d) (Table 1). Most of the deaths occurred in the first week after release (75%) continuing in a variable way (Figure). In the second week the cumulative mortality reached 83% and was 97% one month after the release. Only one male bird remained alive in the field for more than one month, surviving 48 d.

Predators were responsible for 71% of mortalities. In the first year, 78% of birds were killed by predators, 33% by airborne predators and 44% by ground-living carnivores. The rest of the deaths were classified as 11% doubtful and 11% as hunted. During the second year, 67% of deaths were due to predation (44% airborne and 22% terrestrial), with 22% of deaths attributed to hunting and 11% to the doubtful category. There were no significant differences in the incidence of death causes between sexes and years ($F_{(3,32)} = 0{\cdot}270$; $P = 0{\cdot}846$), but birds hunted the second year survived significantly longer ($F_{(7,28)} = 7{\cdot}121$; $P = 0{\cdot}0001$) than the others (Table 2).

The mean dispersion of individuals from the release point was 452 m. There was no difference between birds released in the first year (378 m) and in the second (526 m) ($F_{(1,34)} = 1{\cdot}817$; $P = 0{\cdot}186$). The greatest dispersion (mean maximum distance from the release point travelled by each of the birds) was 851 m for the first year and 1632 m for the second year.

In both years females dispersed further than males, 399 m *vs* 357 m in the first year and 664 m *vs* 389 m in the second (Table 1), but not significantly so ($F_{(3,32)} = 1{\cdot}740$; $P = 0{\cdot}178$).

When home range was studied, defined as the area that each bird needed to carry out normal activities, we observed an overall mean value of 6·2 ha, with 7·1 ha during the first year and 5·4 ha in the second year. There were no significant differences in home range size between males (6·5 ha in year 1 and 7·4 ha in year 2) and females (7·7 ha in year 1 and 3·3 ha in year 2) ($F_{(3,32)} = 0{\cdot}170$; $P = 0{\cdot}915$) (Table 1).

As regards the social behaviour of released birds, none of the farmed partridges joined the wild coveys that lived in the study area. We also never recorded released birds associating with other released birds.

DISCUSSION

The most relevant data in this study are the low survival rates of released partridges (Table 1). These are similar to values (mean survival 12·6 d) reported by Pérez *et al.* (2004) with 2- to 3-month-old partridge chicks released during the summer. These results (Figure) concur with those of Havet and Biadi (1990), Castro Pereira *et al.* (1996) and Carvalho *et al.* (1998), who pointed out that the first 15 d after the release constitutes the critical period for repopulation, as it is during this period when the greatest mortality occurs.

In every repopulation the causes of death could be potentially classified as: inadequacy of the habitat, inability of the birds to obtain food, incidence of disease and predation. In our study, the first cause was not considered a major factor because the area traditionally has been able to

Table 1. *Values of survival, home range and dispersion related to year and sex. Mean ± standard deviation*

Year	Survival (d)		Home range (ha)		Dispersion (m)	
	Males	Females	Males	Females	Males	Females
1	10·2 ± 14·8	8·6 ± 10	6·5 ± 14	7·7 ± 19·5	356·5 ± 193·3	399·2 ± 164·4
2	7·6 ± 4·5	7·8 ± 5·4	7·39 ± 15·7	3·3 ± 6·7	282·68 ± 245·9	664·2 ± 543·7

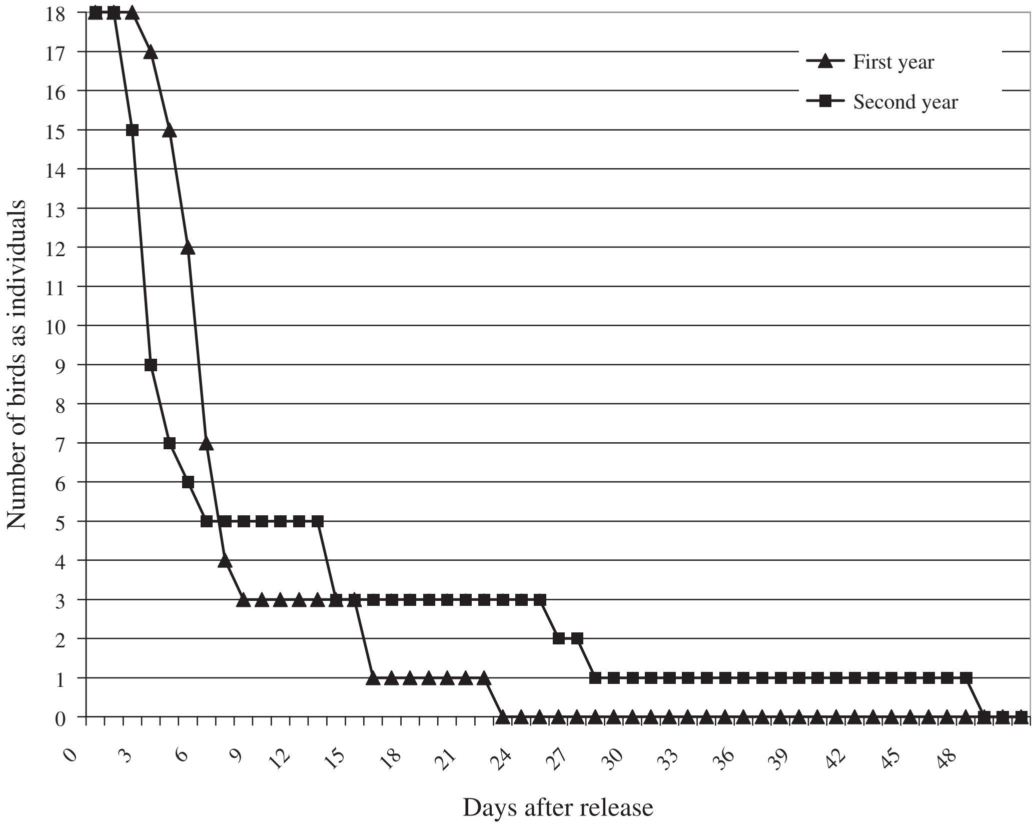

Figure. *Time (d) birds survived in the wild after release each year.*

Table 2. *Values of survival, home range and dispersion related to year and cause of death. Mean ± standard deviation*

Year	Cause of death	Survival (d)	Home range (ha)	Dispersion (m)
1	Air predation	6·2 ± 1·2	1·7 ± 2·9	444·9 ± 202·2
1	Terrestrial predation	6·6 ± 3·7	1·9 ± 3	357·2 ± 192·6
1	Doubtful	14 ± 11·3	29·7 ± 41·7	368·8 ± 67
1	Hunting	9·5 ± 7·8	22·6 ± 30·5	268·1 ± 5·6
2	Air predation	6·3 ± 7·7	2·3 ± 6·3	599·2 ± 435·4
2	Terrestrial predation	5·5 ± 5·1	11·3 ± 22·5	405·1 ± 173·9
2	Doubtful	5·5 ± 5	0·1 ± 0·2	303·5 ± 225·1
2	Hunting	37·5 ± 14·8***	16·5 ± 6·7	923·2 ± 1002·9

***$P < 0{\cdot}001$.

sustain a wild partridge population, with enough landscape diversity to contain the habitat necessities defined by Lucio (1991).

Similarly, the inability to obtain food as a major cause of mortality can be discounted, because in all the cadavers recovered there was evidence of food in the crop and gizzard, such as seeds and insects, even though the partridges did not have access to this food at the rearing farm. Our results are in accordance with Gortázar *et al*. (1997) and Pérez *et al*. (2004). However, the rearing process using manufactured processed feed could produce physiological changes in the gut making the birds less able to assimilate the natural food and resulting in birds nutritionally stressed more susceptible to predation or diseases.

Because the birds came from a commercial game farm with a rigorous sanitary programme, disease was not considered a major cause of low survival, even though this sanitary programme could make birds more susceptible to disease and parasites after release, because they may not have built up natural resistance. The necropsies that were carried out reveal no signs of the major diseases of the species.

Therefore, eliminating these factors and considering the signs of death that were recorded (Table 2), we concluded that predation is a major determining factor of success of repopulation programmes, in accordance with the conclusions of others. Carroll (1990) and Leranoz and Castien (1989) reported predation rates of 88%, Capelo and Castro Pereira (1996) cited

83% (47% due to carnivores, 23% airborne predators and 30% not determined), Gortázar *et al*. (1997) considered predation responsible for 72% of deaths (52% carnivores, 43% airborne predators and 5% hunting) and Pérez *et al*. (2004) assigned 81% of mortality to predators.

However, the reason for failure in our study may not be predation per se, given the survival of wild partridge coveys in the same area. Inappropriate anti-predator behaviour shown by the game farm partridges should be considered (Dowell, 1992).

Our results highlight the low dispersion rates for the red-legged partridges studied (Table 1). One of the reasons for this low dispersion is the fact that they did not join wild coveys present nearby or join together as a new covey, even though this study was carried out during the period in which different family groups join others to form large coveys, for better protection against predation during winter (Beani and Dessi-Fulgheri, 1986). The released birds did not join wild coveys and after some days of small erratic movements, they settled down in an area that covered their nutritional needs. This differs from the results obtained by Leranoz and Castien (1989), who found that the mean distance from the release point increased with time.

Our results show that the spatial demands of the farmed partridges, reflected by their home range (Table 1), are small and that their movements were minimal after they arrived at a place with abundant food, which is not consistent with the normal spatial behaviour patterns of this species. There is a relationship between the small home range and the high rate of predation of the farmed partridges. Wild partridges move continually, trying to distract predator attention and avoid being concentrated at one point. This anti-predator behaviour was not shown by the farmed partridges and might be linked with the low survival rate. In our results the birds that survived longest tended to disperse more and have a larger home range (Table 2).

In conclusion, our findings differ from those of Birkan and Damange (1977) and Capelo and Castro Pereira (1996), who argued that partridges from game farms integrated well with wild populations. The production systems and handling practices of commercial game farms may have modified some ethological anti-predator patterns characteristic of the species, which might have reduced the ability of the birds to adapt and integrate into the wild, which in turn resulted in premature mortality and poor survival.

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