Use of Radiotracking Techniques to Study a Summer Repopulation with Red-Legged Partridge (*Alectoris rufa*) Chicks

J. A. Pérez,* M. E. Alonso,*[,1] V. R. Gaudioso,* J. A. Olmedo,† C. Díez,* and D. Bartolomé*

Departamento de Producción Animal II, Facultad de Veterinaria, Campus de Vegazana, 24071, Léon, Spain; and †Diputación de Valladolid, Spain

ABSTRACT 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 using 54 birds that were 2 to 3 mo old and reared on a commercial game farm. This study aimed to evaluate the effectiveness of repopulations, the behavior in the wild of released partridges, and the possible causes of success or failure of reinforcement population operations.

The releases were carried out during August and September of 2 consecutive years. All birds were equipped with radio transmitter collars to determine their behavior after release. Two release methods were used in yr 1: an acclimatization cage (AC) method and a direct release method on the day of the birds arrival (DR). The aim of the release in yr 2 was to collect data to determine the influence of year conditions using the DR method.

Of the 54 released birds, none remained alive by the time of the reproductive period in the following spring. The mean survival time was 16.79 d for the AC method and was 11.89 and 5 d for the DR method in yr 1 and 2, respectively. Of the recorded mortalities, we assigned 81.13% to predation, 7.55% to hunting, and 11.32% to unknown causes of death, accidents, or starvation. Repopulation was not successful at providing a long-term increase in partridge numbers, with most birds falling victim to predation within 1 mo of release. Dispersion is the maximum distance from the release point at which each bird was located. The postrelease mean dispersion was 437.65 m for the AC method and was 647.57 and 266.07 m for the DR method in yr 1 and 2, respectively.

(*Key words*: chick, radiotracking technique, Red-Legged partridge, repopulation method, summer)

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INTRODUCTION

Historically, Spain has always been a privileged territory in which to maintain game birds such as the Red-Legged partridge, given the country's orographic, climatic, landscape, and cultural characteristics. However, since 1986 an important decrease in wild populations of this species has been measured (Redondo, 1993). The Red-Legged partridge population, as measured by the number shot each hunting season, decreased by 25% between 1990 and 1994. According to Nadal (1992), this alarming decrease of the species is due more to its decline 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 larger populations are still maintained. Moreover, this phenomenon also affects other natural populations of partridges throughout their world distribution (Aebischer and Potts, 1994).

Release of birds from game farms is commonly used to increase the scarce production of wild populations of Red-Legged partridges and to try to reverse the progressive contraction of its area of distribution. In Spain, about 4 million birds are released into the wild every year to increase numbers for hunting and to reinforce natural populations by trying to increase the reproductive success of the species (Coll, 1991). However, in the majority of the cases repopulation operations are inadequately performed. Birds are not subjected to the appropriate health and genetic controls, which increases the risk of spread of some pathogens and the possibility of hybridization of autochthonous partridges. Game farm birds could be obtained by crossing Red-Legged partridges with other species (e.g., Chukar, Barbary, or Rock partridges) with the purpose of propagating birds that are economically more profitable due to larger body dimensions and faster growth (Pérez and Díez, 2002). It is also very important to carry out habitat improvements before bird release.

Production systems and handling techniques used on game farms are highly technical and intensified, producing changes in behavior patterns that are not characteristic

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[1]To whom correspondence should be addressed: dp2mav@unileon.es.

Abbreviation Key: AC = acclimatization cage; DR = direct release.

of wild birds (Gaudioso et al., 2002). All of these factors, together with the imprinting process that the birds inevitably undergo, cause long-term physiological and ethological modifications that consequently result in serious problems with adaptation and integration in the wild (Lucio, 1992).

The most common repopulation method involves the release in summer time of 2- to 4-mo-old Red-Legged partridge chicks, following the recommendations of Leranoz and Castien (1989). Furthermore, Capelo and Castro Pereira (1996) stated that repopulations were more successful if carried out in summer using 2-mo-old chicks.

Despite these previous findings, the enormous differences among habitats alone justify the undertaking of similar research in another habitat. In this study, the grain farming environment represents one-fifth of the Red-Legged partridge distribution in the Iberian Peninsula.

The purposes of this study were to evaluate the capacity of game farm reared birds to adapt to and survive in a natural environment and to determine the most frequent causes of mortality. Our long-term goals were to develop a greater understanding of the eco-ethological parameters that determine adaptation of released game farm Red-Legged partridge chicks to the wild, to better understand the management of released Red-Legged partridge populations, and to better understand how to increase the success of repopulations in the future.

MATERIAL AND METHODS

Study Area

The study was carried out on a property of 308 ha located in Valladolid County, in the Autonomous Community of Castilla and León. The area has traditionally been able to sustain partridges and other game species such as rabbits and hares. In previous years, replanting on the property has left it with a diversity of plant species that provides shelter and food, including arboreal species (22.89% of the study area), such as *Pinus* spp. and *Cupressus sempervirens*, and bushy plants (37.21%), such as *Citissus* spp., *Crataegus* spp., and *Rubus* spp. The study area also included some cultivated lands (36.98%) with sunflower (*Helianthus annuus*), lucerne (*Medicago sativa*), and barley (*Hordeum distichon*). The rest of the study area consisted of partridge-handling facilities (0.52%) and buildings (2.40%).

The environmental conditions during the study periods were typical for the Northern Meseta in Spain. In 1998, during the first study period, temperatures ranged from a minimum of 1.6°C in October to a maximum of 38.3°C in August with a mean monthly rainfall of 30.7 mm. In 1999, temperatures ranged from a minimum of 4.4°C in October to a maximum of 36°C in August with a mean monthly rainfall of 38.7 mm (Gráficas Calima, 2001).

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

Birds

Fifty-four 2- to 3-mo-old Red-Legged partridge chicks from a commercial game farm were used. On the commercial game farm, newly hatched chicks were placed in brooding rooms within protective rings with the aim of maintaining them close to a heat source for at least the first 8 to 10 d posthatch. The diameter of the circle allowed for an animal density of 100 chicks per m^2. After 10 d, the birds were then allowed access to the whole room, which was heated day and night at 28 to 30°C, until they reached 25 d of age. From 25 to 60 d of age, the birds were given heat during the night and part of the day and allowed access to a small grass area with an animal density of 40 to 50 chicks per m^2. At 60 d of age, they were placed in large cages in which they could fly, until the beginning of the experiment. All birds used in the study were subject to health and genetic checks. The mean chick weight at the commencement of the study was 332.41 g.

Methods

Yr 1: Acclimatization Cage Method. Open-floored acclimatization cages (AC) of 4 m^2 (4 × 1 × 1 m) were placed directly on the ground over areas with typical vegetation. Within each cage was a drinking trough of constant level and dispersed cereal seeds on the ground. The birds were introduced into each cage in groups of 2, 6 d before their release. The release consisted of the opening of the cage door at the dawn so that the birds could exit voluntarily following sunrise and avoid any manipulation that forced their exit. A total of 24 birds were released using this method.

Direct Release Method. This method used cages (40 × 30 × 30 cm) consisting of a wooden base covered with a wire mesh in a triangle form that allowed the birds to see the environment. At 1000 h on the day birds arrived on the property, they were placed in the cages, and remained there for 5 min before their exit was permitted in order to minimize manipulation stress. Eighteen birds were released using this method.

Yr 2. In order to determine the year effect on the variables measured, we repeated the release the following year. In yr 2, a total of 12 chicks were released, using the direct release (DR) method only.

The releases in both years occurred during 1 d of each of 4 consecutive wk between late August and mid-September, coinciding with the rearing period of autochthonous Red-Legged partridge chicks born in freedom. Three different release points were used to avoid bird concentration in a point, which would act as focus of attraction for predators (Church et al., 1984).

During yr 1, 6 birds were released by the AC method and 6 by the DR method every release day, 2 per method at each release point, except the last day, when we only released birds by the AC method due to transport problems with the birds of the DR method. During yr 2, only 3 birds were released by DR method, 1 at each release point every release day.

Radiotracking Localization

All the birds were equipped with Biotrack[2] radio transmitter collars, weighing of 9.8 g (less than 5% of BW) and with an autonomous operating life of 11 mo. A metallic numbered ring was placed on the right leg of each chick.

After release, individual birds were tracked daily on 5 to 7 d per wk, using a Yaesu receiving unit[3] 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 significant changes in the reception intensity indicated that the bird was alive.

Causes of Death

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

- Air predation (cause 1): cadaver with fleshed bones and feathers plucked cleanly with the quill attached.
- Terrestrial predation (cause 2): mainly only the 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 bird remaining was the cecum of the large intestine.
- Unknown cause of death (cause 3): when it was not possible to attribute death to one of the causes listed above or death was due to starvation, illness, or accident. This category also included the loss of the radio transmitter.
- Human hunting (cause 4): collar radio transmitter with clear signs of human hunting activity (presence of pellets) or necklace recovered from legal hunters.

Whenever possible, the cadaver was picked up, and a formal necropsy was carried out to examine body condition and plumage state, assess the presence of food in the crop and gizzard, and identify symptoms of common pathologies.

Data Analysis

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

The data were analyzed by one-way ANOVA (Dixon, 1983) to assess the significance of differences between release methods using a computer program.[4] The Newman-Keuls test (Dixon, 1983) was chosen for the posthoc comparison of means. Differences with $P < 0.05$ were considered significant.

RESULTS

Yr 1

There were no differences between release points for any of the variables measured: survival ($F_{(2,36)} = 0.538$; $P = 0.588$), dispersion ($F_{(2,36)} = 1.416$; $P = 0.256$), and home range ($F_{(2,36)} = 2.281$; $P = 0.117$). The radiotracking carried out on all the birds allowed us to calculate a total mean survival of 14.34 d following release. There was no difference in bird survival duration between the AC method (16.79 d) and the DR method (11.89 d) ($F_{(1,40)} = 0.654$; $P = 0.42$).

In both groups, most of the deaths were registered in the first week after release, 54.17% for AC and 77.78% for DR. In the second week, the cumulative mortality reached 58.33% of the repopulated partridges from the AC treatment and 88.89% from the DR treatment. Only 7 birds remained alive in the field for more than 1 mo, 5 from AC and 2 from DR. Finally, only 2 partridges survived more than 2 mo, 1 from each method (Figure 1).

Analysis of the causes of death indicated that predators were responsible for 81.25% of mortalities. Of birds released by the AC method, predators killed 79.17%, with 50.00% of birds killed by airborne predators and the remainder by ground-based carnivores. The rest of the deaths for the AC birds were distributed between 16.67% classified as unknown causes and 4.17% as hunted. Of birds released by the DR method, 83.33% of deaths were due to predation (50.00% airborne and 33.33% terrestrial), with 11.11% of deaths attributed to hunting and 5.56% to unknown causes. There were no differences between the 2 release methods in the incidence of causes of predation ($F_{(1,40)} = 0.009$; $P = 0.93$).

Table 1 presents data relating to mortality, home range, and dispersion for each of the release methods. There were no differences between home range and dispersion, other than for birds that were released by the DR method and then killed by human hunting, which had a significantly greater home range area and dispersion. The mean dispersion of individuals from the release point was 542.61 m. There was no difference in dispersion between birds released by the AC method (437.65 m) and birds released by the DR method (647.57 m) ($F_{(1, 40)} = 3.251$; $P = 0.079$). The greatest dispersion, defined as the maximum distance traveled by each of the birds from the release point, was 940.2 m for the AC method and 1,739.7 m for the DR method. The overall mean home range was 11.16 ha, with no differences between AC birds (9.43 ha) and DR birds (12.89 ha) ($F_{(1,40)} = 0.284$; $P = 0.59$).

Yr 2

There were no differences between release points for any of the variables measured: survival ($F_{(2,24)} = 1.041$; $P = 0.369$), dispersion ($F_{(2,24)} = 2.038$; $P = 0.152$), and home range

[2]Biotrack Ltd., Wareham, Dorset UK.
[3]http://www.yaesu.com.
[4]SPSS for Windows, Version 10.0, SPSS Inc., Chicago, IL.

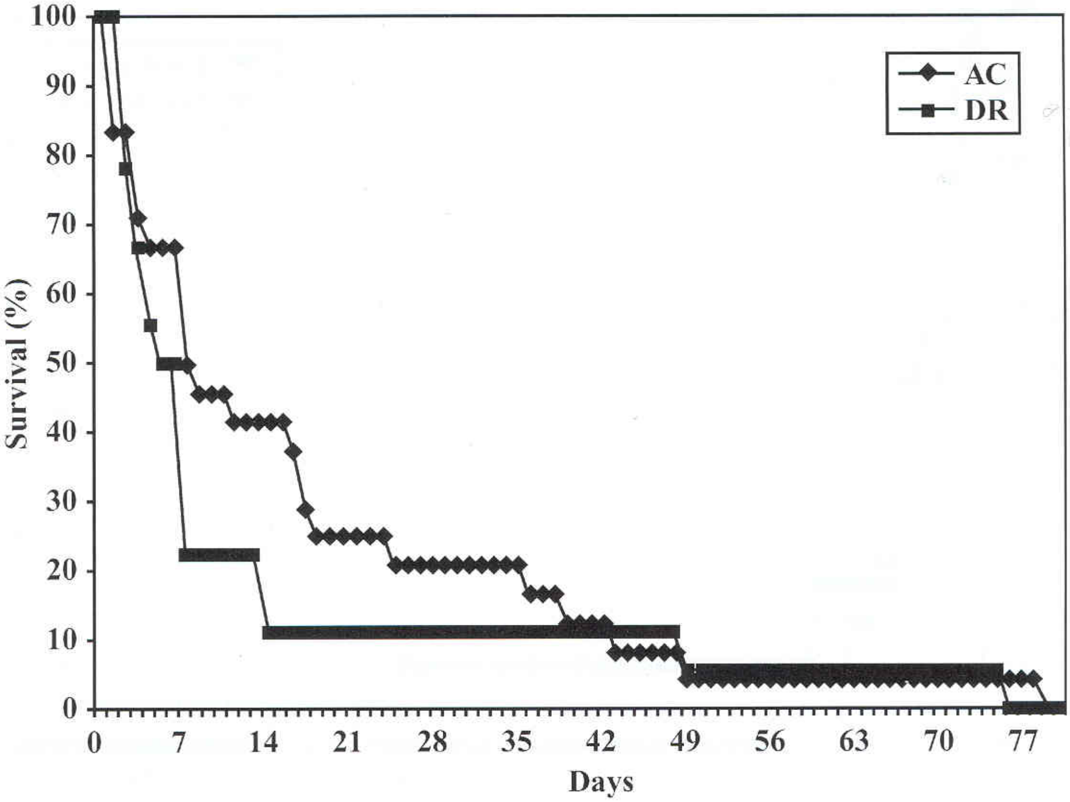

FIGURE 1. Survival profile of released birds (yr 1).

($F_{(2,24)}$ = 0.994; P = 0.384). We also found no differences between the mean survival rates for the 2 yr ($F_{(1,28)}$ = 1.385; P = 0.24), with a mean survival of 11.89 d in yr 1 and 5.17 d in yr 2.

Most of the deaths were recorded in the first week after release, with 77.78% in the first week for yr 1 and 75% for yr 2. In the second week, the cumulative mortality reached 88.89% for yr 1 and 91.67% for yr 2. Finally, only 2 birds (from yr 1) remained in the field for more than 1 mo (Figure 2).

Of birds released the second year, 75.00% of the recorded deaths were due to predation (41.67% air predation and 33.33% terrestrial), with 25.00% of losses considered due to unknown causes of death. There was no difference between years ($F_{(1,28)}$ = 0.025; P = 0.87) in the incidence of different causes of predation, and the interaction between year and cause of predation was not significant (Table 2).

When analyzing dispersion data of the individuals, we obtained a mean value of 494.97 m, with dispersal in yr 1 (647.57 m) being greater than that for yr 2 (266.07 m) ($F_{(1,28)}$ = 7.173; P < 0.05). The maximum dispersion recorded was 1,739.7 m in yr 1 and 466.4 m in yr 2. The overall mean home range was 9.76 ha with no differences between years ($F_{(1,28)}$ = 0.957; P = 0.34), 12.89 ha for yr 1, and 5.06 ha for yr 2.

In both years, no released bird was subsequently located in the area of the acclimatization cage, and released birds were never integrated into coveys of wild partridges. On

TABLE 1. Mean values of survival, home range, and dispersion categorized by release method and cause of death

Release method	Cause of death	Survival (d)	Home range (ha)	Dispersion (m)
AC[1]	Air predation	19.42	4.88	358.74
AC	Terrestrial predation	12.14	9.88	399.99
AC	Doubtful	9.00	22.98	722.40
AC	Human hunting	49.00	6.74	509.20
DR[2]	Air predation	5.67	3.36	552.70
DR	Terrestrial predation	5.83	5.45	482.50
DR	Doubtful	3.00	0.01	439.30
DR	Human hunting	62.50	84.55***	1,673.80***

[1]AC = acclimatization cage release method.
[2]DR = direct release method.
***$P \leq 0.001$.

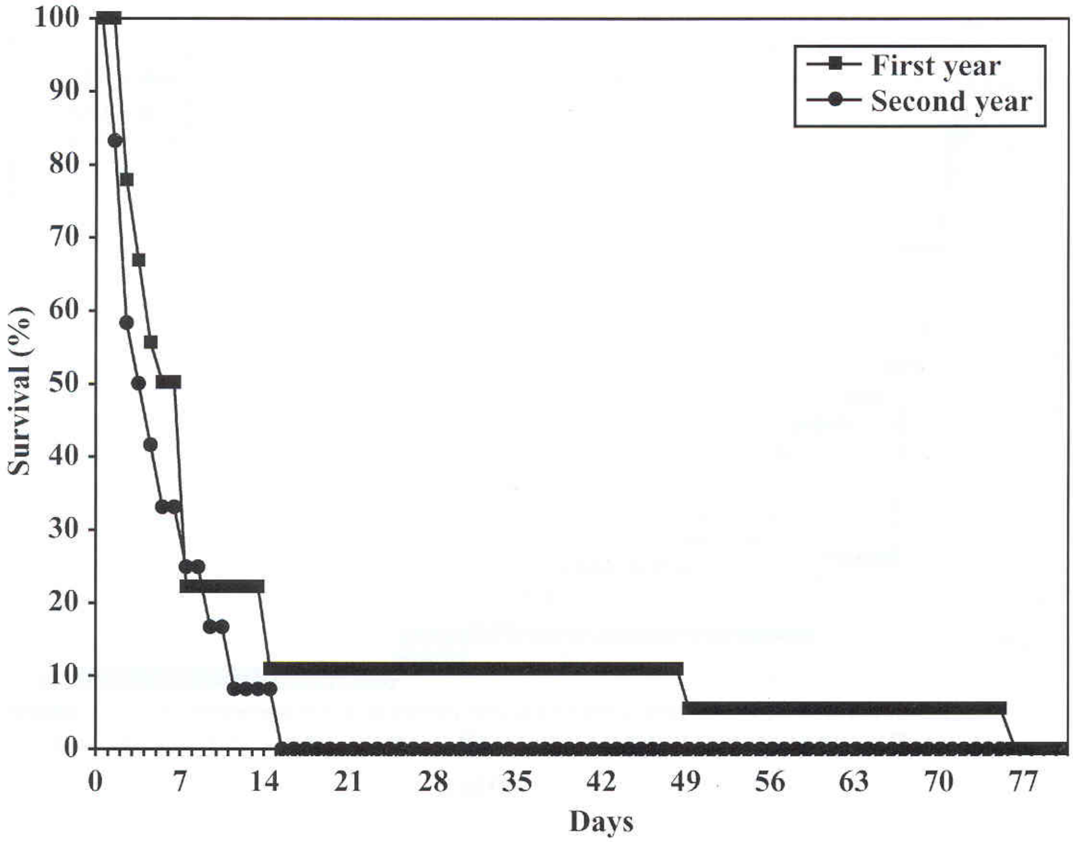

FIGURE 2. Survival profile of released birds (yr 1 and 2).

some occasions, introduced birds were observed in the proximities of a wild covey, but integration could not be confirmed because such birds were never observed with the wild covey again in other locations. Formations of groups of 2 birds coming from the same release were verified on at least 5 occasions (3 in yr 1 and 2 in yr 2), and these birds had numerically longer survival times.

DISCUSSION

Survival

Yr 1. The use of AC produced numerically higher mean survival, but the absence of statistically significant differences between the release methods shows that there were no advantages in using these cages. Furthermore, the AC method was more expensive than DR and required more handling. These results are different from those of Leranoz and Castien (1989).

In addition, there were no differences between release methods in the causes of death, which indicates that the time partridges spent in the acclimatization cages did not improve their development of survival and antipredatory strategies. This finding could be due to the behavioral changes undergone during captive breeding or the limited time the partridges spent in the cages (1 wk).

Yr 2. The aim of the second year's research was to study the year effect, and following the absence of differences between release methods in yr 1, only the DR method was used for yr 2. This method provides some handling and methodological advantages to the owners of game reserves and is inexpensive and easy to perform.

In the second year that the DR was used, the survival rate was very low. This result could be due to the differences in

TABLE 2. Mean values of survival, home range, and dispersion depending on the release year and cause of death

Year	Cause of death	Survival (d)	Home range (ha)	Dispersion (m)
1	Air predation	5.67	3.36	552.70
1	Terrestrial predation	5.83	5.45	482.50
1	Doubtful	3.00	0.01	439.30
2	Air predation	5.60	7.39	282.68
2	Terrestrial predation	2.50	0.52	251.90
2	Doubtful	8.00	7.24	257.28

the field condition of the study area, because the released partridges in yr 2 found less cultivated lands and more fallow ground that offered less protection against aerial predators. In addition, as the feeding areas were smaller the birds would have been more concentrated, which could have attracted predators to them, but the fact that there was no statistically significant difference between the 2 yr suggests that there was not a year effect in our results.

General. Considering release methods and years together, the fact that stands out is the low survival rate of released birds, which is in agreement with similar studies carried out with radiotagged Red-Legged partridges. Gortázar et al. (1997) recorded a mean survival time of 10 d after a summer repopulation with 3-mo-old chicks, a survival time very similar to ours of 12.57 d.

From the survival curves (Figures 1 and 2), our results coincide with Havet and Biadi (1990) and Castro Pereira et al. (1996), who pointed out that the first 15 d after release constitutes the critical period for repopulations, as it is during this period when the greatest mortality occurs. The results of the analysis of cause of death in our study were not in accordance with those of Carroll (1990), who considered deaths registered during the first week as being due to radio transmitters and handling manipulation.

For the causes of death, the contributing factors potentially include inadequacy of the habitat, inability of the birds to obtain food, incidence of disease, and predation. For our study, we did not consider the first cause as a major factor because the area traditionally has been able to sustain a wild partridge population with enough landscape diversity to contain the habitat necessities defined by Lucio (1991).

Similarly, we would discount an inability to obtain food as a major cause of mortality, because in only one cadaver was there no evidence of food. In the others, even without previous acclimatization, there was food in the crop and gizzard. The food contents comprised seeds and insects, even though the partridges did not have access to insects at the rearing farm. Our results are in accordance with Gortázar et al. (1997), who observed the ability of game farm partridges to forage and obtain natural food without having additional artificial feeding troughs.

With regard to disease as a possible contributor to mortality, because the birds came from a commercial game farm with a rigorously sanitary program, we do not consider that disease was a major cause of low survival. In addition, the necropsies that were carried out did not reveal signs of the major pathologies of the species.

Therefore, eliminating other factors and considering the signs of death that were observed, we determined from our study that predation was a major factor in the success of repopulation programs. This finding is in accordance with the conclusions of Leranoz and Castien (1989), Carroll (1990), Castro Pereira et al. (1996), and Gortázar et al. (1997), who considered predation to be the greatest obstacle when undertaking partridge repopulations.

However, it seems unlikely that predation per se is the only reason for failure, given the survival of wild partridge coveys in the same area. We need to consider inappropriate antipredator behavior shown by the studied game farm partridges, also highlighted in previous studies (Dowell, 1992). Released birds never integrated themselves into wild coveys, and, as authors such as Tinbergen (1951) and Beani and Dessi-Fulgheri (1986) have demonstrated with their studies, gregariousness is clearly a protection behavior shown by different species of animals. On the other hand, it is also significant that birds that grouped with others had a greater survival time once liberated. There appears to be a need for further experimental studies to evaluate the impact and benefits of predator control on Red-Legged partridge repopulations.

Dispersion and Home Range

Yr 1. Given that the level of dispersal did not differ between the AC and DR methods, and that none of the partridges were subsequently located in the surroundings of the acclimatization cage, our results do not support the hypothesis that the cages are used as a refuge and a place to feed as suggested by Leranoz and Castien (1989).

Yr 2. The significant differences in the dispersion between the first and the second year of DR could be explained by 2 possible hypotheses: 1) the year effect, with variations in the habitat that study birds found, and 2) the direct relationship between survival and dispersion.

We discard the first hypothesis because the conditions of the study area were less favorable in the second year, with less cultivated lands and more restricted feeding areas, which should have induced greater dispersion in searching for food, which did not happen. The second hypothesis is in accordance with the results of Leranoz and Castien (1989), who pointed out that there is a tendency to progressively increase the mean distance from the release point as time passes. However, in our results, the dispersion did not increase gradually with the partridges' survival but was greatest around a medium localization date. After this, the birds established themselves in a determinate area without great movements in the following days (Pérez and Díez, 2002). Given that in yr 2 all the released partridges died within 2 wk, we concluded that they did not have enough time to disperse and search for better areas. On the other hand, the differences between the mean dispersion values were primarily due to large values recorded for a few birds, resulting in a large standard deviation.

General. Our results showed low dispersion rates for the Red-Legged partridges. We consider that one of the reasons for this low dispersion was the inability of game farm partridges to join wild coveys hatched on the research property, such that after some days of small erratic movements, they settled down in an area that covered their nutritional needs. This finding does not agree with the results obtained by Leranoz and Castien (1989), who argued that the mean distance from the release point increases with time.

From our results, it is clear that the space demands of the farm partridges, reflected in their home range, are small and that their movements can be considered to be minimal after they arrive at a place with abundant food. It was also observed that the chosen locations for most of the individuals, independent of release place and date, were partridge-handling facilities used in other experimental protocols, which indicates a clear alteration of the behavior patterns characteristic of the species.

On the other hand, we can establish some relationship between the home range and the high rate of predation of farmed partridges. Wild partridges move continually, to distract predator attention and to avoid being concentrated at one point. The farmed partridges did not exhibit such antipredator behavior, which may explain their low survival rate.

In conclusion, our results differ from those of Birkan and Damange (1977) and Capelo and Castro Pereira (1996), who argue that the integration of partridges from game farms into wild populations occurs at a very satisfactory level. These studies also indicated that repopulations with chicks of similar ages to the chicks in the wild coveys gave better results for integration, something that we did not observe.

Our conclusions are that the production systems and handling practices of commercial game farms have considerably modified the ethological patterns characteristic of the species. In addition, the inability to adapt and integrate into the wild prevented survival for sufficient time for the birds to complete their reproductive cycle, once released to the field.

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