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In order to evaluate the success of a population of red-legged partridges *Alectoris rufa* reintroduced into a 33.7 km^2 study area, we estimated 15 demographic parameters from 1996 to 1999 by regularly monitoring the population through winter, spring and summer mapping censuses. During the study period, late winter population and spring dispersal decreased, pair number, brood number, brood production rate, chick survival and over winter losses were stable, whereas average brood size, juvenile number, age ratio, adult spring to summer survival, late summer population, and population growth rate from spring to late summer all increased. The population showed a moderate improvement in the overall productivity, mainly related to increased production of young and to a decrease in adult mortality. The improvement in breeding performance took place, in particular, after the second year of study with the conclusion of the releasing session of reared birds.

Key words: Alectoris rufa, central Italy, demography, red-legged partridge, reintroduction

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About 27% of Galliform species are threatened with extinction compared to 12% of bird species on a global scale. Moreover, up to twothirds of unthreatened Galliform species are declining (Rands 1992, Potts & Aebischer 1995, UNEP-WCMC 2001). In Europe, most Galliform species have an unfavourable conservation status and are classified as 'Species of European Conservation Concern' (SPEC) at several levels, each of which depends on various factors, such as population trend and distribution, and whether they are concentrated or not in Europe (Tucker & Heath 1994).

The red-legged partridge *Alectoris rufa* is an important game-bird species in the western Palaearctic due to its commercial value, and it is classified as SPEC 2 based on two factors: a marked population decline and a population spread limited to Europe. The decline in red-legged partridge has occurred throughout its range, and the species is considered vulnerable (Aebischer & Potts 1994,Tucker & Heath 1994, Aebischer & Lucio 1996, Borralho, Carvalho, Rego & Vaz Pinto 1999). The most important causes of the decline are the intensification of agriculture and the related loss of suitable habitats. However, in some southern European areas such as in Italy, where habitat changes are still restricted, it is possible that over-hunting has played an important role in reducing population density thus causing extinction of species at local levels (Aebischer & Lucio 1996). Moreover, in order to sustain the heavy hunting pressure, massive releases of reared birds are carried out in several countries, which lead to consequent problems including overshooting of wild stocks, increased predation pressure and increased spreading of diseases (Aebischer & Lucio 1996, Gortazar, Villafuerte & Martin 2000). Often, hybrids of *A. rufa* X *A. chukar* and *A. rufa* X *A. graeca* are used for restocking, and this might disrupt the genetic pool of wild populations and cause productivity reductions in wild populations because of the low reproductive performance of the hybrids (Potts 1989).

In the areas where the species is extinct and the habitat can still be considered suitable, reintroductions may act as an effective tool to restore the original range and to re-establish wild populations. However, a major problem lies in assessing whether the reintroduced populations can effectively be self-sustaining in the long term, and whether they can reach reproductive performances comparable to those of natural populations (Dowell 1992).

Captive-born partridges have to be used for reintroductions as few, if any, of the wild populations can sustain the removal of several hundreds animals per year to be translocated into reintroduction areas. Dowell (1992) identified four main factors likely to affect the reintroduction success of small game species when farm-bred individuals are used: a) genetic and behavioural differences between reared and wild animals, b) physiological problems and disease resistance, c) density-dependent predation at release sites and d) habitat changes. Consequently, restocking and reintroduction programmes need to solve problems concerning acclimatisation, sanitary control, genetic purity and diversity, and low survival and reproductive performances (Beck, Rapaport, Stanley Price & Wilson 1994, Kleiman, Stanley Price & Beck 1994, Millan, Gortazar & Villafuerte 2001, Millan, Gortazar, Tizzani & Buenestado 2002).

Despite the widespread use of releasing captive-born red-legged partridges, little information is available on the success of this tool (Brun & Aubineau 1989, Havet & Biadi 1990, Carvalho, Castro-Pereira, Capelo & Borralho 1998, Gortazar et al. 2000). Moreover, the majority of studies deal with release success, i.e. with the survival of released birds, rather than with the effectiveness of the restocking and reintroduction programmes of enhancing population levels or re-establishing natural and self-sustaining populations.

In this paper we describe the demography of a reintroduced population of red-legged partridges in central Italy where the species went extinct during the first decades of the 20th century (Massi 1990, Baccetti 1996, Foschi, Bulgarini, Cignini, Melletti, Pizzari & Visentin 1996). Our research was conducted with the aim of evaluating the reintroduction success by focusing on the dynamics of the reintroduced population, and comparing the demographic parameters with those of other wild populations in Europe.

Material and methods

Study area

The 33.7-km^2 study area is located in a hilly zone in the southern province of Siena in Tuscany, central Italy, at 300 - 600 m a.s.l.. Annual precipitation averages 752 mm with two peak seasons in April (68.1 mm) and November (111.2 mm), respectively, and with a minimum season in July (30 mm). The average annual temperature is 13.7°C (January: 5.5°C; July: 23.9°C). Land use classes (detected by aerial photographs at a scale of 1:10,000 and direct surveys) include oak *Quercus pubescens* and *Q. ulmifolia* woods (7.9 %), gullies and scrub (15.4%), fallow fields (4.0%), sheep pastures (15.4%), crops (winter wheat, barley, sunflower and alfalfa; 35.9%), olive tree groves and vineyards (1.0%) and human settlements (3.3%). Hedgerows and margins with herbaceous vegetation covered 17.1% of the study area. Cereal fields are treated with herbicides only. Gullies and scrub decreased by 5.1% during the study period and fallow fields by 78.3%, whereas pastures and crops increased by 9.2 and 17.7%, respectively. Woods, olive tree groves, vineyards, human settlements and hedgerows remained stable. The study area is situated at the southern boundary of the historical range of the red-legged partridge, and no partridges were present in the region before the beginning of the study, as the species became extinct in the first decades of the 20th century. Since 1994, partridge hunting has been prohibited in the study area, and in the surrounding areas, where red-legged partridge is a protected species, hunting is mainly carried out on pheasant *Phasianus colchi-*

cus, European hare *Lepus europaeus*, wild boar *Sus scrofa* and roe deer *Capreolus capreolus*.

Releases

A total of 2,132 captive-reared red-legged partridges aged 90-120 days were released in the study area from 1995 to 1997 (1995: 632; 1996: 1,000; 1997: 500). In order to increase genetic diversity and to avoid inbreeding in the initial population, partridges came from three different game farms. These farms were free from parasites (coccidian and helmints) and other diseases, and sanitary treatments were not applied during the acclimatisation period. Each bird was checked for morphological indexes of hybridisation with *Alectoris graeca* and *A. chukar*, in particular for the double black bar on the feathers covering the flanks. Releases took place in late summer (August-September) in an acclimatisation pen of 5 ha which contained 20 aviaries of 2 x 4 x 2 m each. In each aviary, 20-30 birds were maintained for at least seven days after which the partridges were released in flocks, aviary by aviary, with a time interval of two days between flocks. We used this method in order to create group relations and to avoid the formation of excessively large groups beyond the size of natural coveys. All partridges were tagged with numbered ponchos of a different colour for each year of the study period. To reduce mortality of released birds, and to increase survival and reproductive success, 107 feeding sites kept all year round, were placed scattered in the study area and equipped with automatic feeders and watering troughs. Crows *Corvus corone cornix* and magpies *Pica pica* were controlled by use of Larsen traps, and red foxes *Vulpes vulpes* culled by night-shooting. Predator control was performed with particular care in the surrounding areas of the acclimatisation pen in late summer and autumn, but was extended to the whole study area during the breeding season.

Field procedures

The population was monitored all year round from January 1996 to October 1999 by means of censuses of winter coveys, pairs and broods carried out by use of the mapping method (Blondel 1969, Pépin 1983). Searching effort was equally distributed by a net of transects (127.6 km in total) that covered the whole study area. Every two weeks, transects were completely covered by five trained observers. Surveys were carried out during the first three hours after dawn and the last three hours before dusk. A tape-recorded call was used in spring to increase pair detectability (Pépin 1983, Ricci 1985, Gibbons, Hill & Sutherland 1996). We used the colour and the number on the ponchos to distinguish between wintering coveys and pairs, whereas broods were identified by age and by the ponchos of accompanying adults. When few or no marked birds were present in the population, simultaneous observations were used to identify different coveys, pairs and broods (Gibbons et al. 1996). The age of the chicks was assessed from the moult stage and were classified as < 10 days old, 10-30 days old, 30-60 days old, and > 60 days old (Alkon 1982). Observers plotted the locations of partridge sightings, calling birds, tracks and droppings on 1:10,000 aerial photographs, recording the number of detected birds, the colour and the number of the ponchos, and, for juveniles, their age classes.

Each year we estimated the density of nesting crows and magpies by complete counts of nests in early winter, and the abundance of foxes (number of individuals/km) using nocturnal transects (37.6 km) and spotlight in early spring (Von Schantz & Liberg 1982, Fasola, Prigioni, Barbieri & Meriggi 1985).

Estimated population parameters

For each year we assessed the following demographic parameters from the collected data: 1) Late winter population size and density; 2) early spring population and density; 3) spring dispersal (estimated as the percentage difference between late winter and early spring population and thus including winter mortality); 4) pair number and density; 5) brood number and density; 6) percentage of successfully reproducing pairs, i.e. the percentage of pairs accompanied by at least one young; 7) average brood size at hatching (the arithmetic mean of hatched eggs per successful nest); 8) average brood size (the arithmetic mean of the chick number per brood in all age classes); 9) chick survival rate (CSR; estimated as the reciprocal of the percentage difference between the average size of broods > 30 days old and at hatching; for the pooled study years CSR was estimated to > 60 days old; 10) juvenile number and density in late summer (juveniles being the birds born in the year and surviving until late summer); 11) age ratios (the number of juveniles in summer over the number of adults in spring and over the number of adults remaining after the breeding season); 12) adult losses from spring to summer (percentage difference between the number of partridges in early spring and the number of adults in late summer); 13) late summer population and density; 14) population growth rate from spring to late summer (percentage difference between the population in late summer and in early spring); and 15) over-winter losses (percentage difference between the late summer population and the early spring population of the following year).

Table 1. Density of nesting pairs of hooded crow and magpie pooled, and abundance of foxes during 1995-1999.

Year	Crow pair density (Number/ km^2)	Fox abundance (Number/km)
1995	5.6	0.5
1996	3.2	0.1
1997	0.9	0.1
1998	1.7	0.1
1999	1.7	0

Late winter population of 1996, 1997 and 1998 included the birds released in the previous year. In the winter of 1999, no partridge released in the previous summer were present as the releases stopped in 1997.

Although spring dispersal included late winter mortality of red-legged partridges, we believe that the dramatic decrease recorded in some years at the end of the winter (concentrated within a small interval of 15-20 days) was mainly due to pair formation and to the consequent territoriality and spacing behaviour of the paired partridges (Potts 1980, Green 1983). Because of the small number of successful nest found, and because of the number of hatched eggs per nest to be constant between years (Potts 1980), we calculated the average brood size at hatching by pooling the study years. Average brood size at the different age classes was calculated by taking into account only the broods for which all the chicks were seen, i.e. broods observed in open and low vegetation. In order to avoid overestimation of summer population and underestimation of winter losses due to the presence of released birds, we calculated late summer populations in 1996 and 1997 without counting the birds released in these years, and the over-winter losses excluding the partridges released in the previous year that survived until the next spring.

Statistical analyses

Parametric tests were used when their assumptions were met; otherwise, non-parametric tests were used to detect significant differences in demographic parameters between the various study years. In particular, we used the Student t-test to verify the differences between the averages of two sets of data; the One-way ANOVA and Bonferroni's post-hoc to test for differences between the average values of more than two groups; the χ^2-test

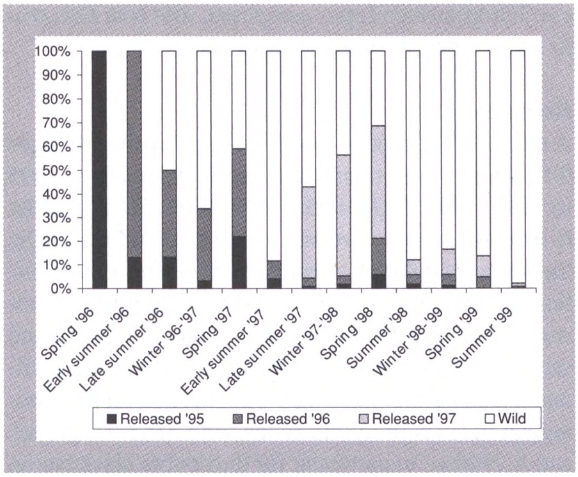

Figure 1. Composition of the reintroduced population of red-legged partridges according to season after the initial release in 1995 and the release in 1996 and 1997 with indication of the shares of released and wild birds. Note that early summer ~ before releases and that late summer ~ after releases.

to compare two or more observed frequency distributions; and a test of equality of proportions to detect significant differences between two or more proportions or percentages. The statistical precision with which we estimated the average brood size each year at the different age classes was measured as the ratio of the standard errors of brood size to the mean (Potts 1986). We adopted the minimum significance level of $P = 0.05$, and performed all statistical analyses by use of the SPSS PC plus version 10.0 for Windows (SPSS Inc. 2000).

Results

Predator control and abundance

During 1995-1999, a total of 975 crows, 1,195 magpies and 149 red foxes were killed in the study area. Predator control occurred throughout the study period and still continues. The combined nesting pair density of crows and magpie decreased in the study area by 66.1% during the study period. The decrease of the abundance index of foxes was more marked, reaching 0.0 individuals/km at the end of the study (Table 1).

Table 2. Data on coveys and other parameters of red-legged partridges in the reintroduced population in the winters of 1995/96-1998/99.

	Coveys			Partridges		
Winter	Number	Average covey size (± 1SE)	Range	No. of partridges	Unmarked partridges (%)	Density (Birds/km^2)
1995/96	41	9.8 (1.67)	3-19	402	0.0	11.9
1996/97	79	9.6 (1.20)	1-65	758	66.2	22.5
1997/98	63	7.3 (0.74)	1-35	460	43.6	13.6
1998/99	53	5.2 (0.43)	1-15	277	83.4	8.2

Table 3. Data on pairs, unmarked pairs (with at least one unmarked individual) and unpaired birds in the reintroduced population of red-legged partridges during spring in 1996-1999.

Year	Pairs Number	Pairs/km²	Unmarked pairs (%)	Unpaired birds
1996	117	3.5	0.0	1
1997	125	3.7	62.1	39
1998	126	3.7	58.7	6
1999	120	3.6	93.0	0

Table 4. Number (N) and average brood size of the reintroduced population of red-legged partridges according to age class from hatching (0) to the age of > 60 days old. Data are pooled for the years 1996-1999.

Age class	N	Average brood size	SE	Range
0	14	9.8	0.88	4-15
< 10 days old	41	8.3	0.52	2-16
10-30 days old	79	7.7	0.34	1-15
30-60 days old	77	6.4	0.31	1-12
> 60 days old	52	5.9	0.32	1-15
		$F_{4,258} = 8.50$; $P < 0.0001$		

Population composition

Starting in spring 1996, the reintroduced population of red-legged partridges showed an overall increase in the wild portion of the population, i.e. the birds born in the wild. In particular, the increase was marked in early summer after reproduction and before the releases. After the late-summer releases in 1996 and 1997, we observed a reduction in the wild portion of the population that was even more marked in the next spring, before the clutch hatching. In 1998 and 1999, the density of released birds decreased dramatically in the reintroduced population (Fig. 1).

Late winter-early spring population

The population recorded in late winter increased from 1996 to 1997 and then markedly decreased; the decrease was 63.5% in partridge number and density, and 32.9% in covey number. The average covey size decreased by half of the first-winter value ($F_{3,254} = 3.16$, $P = 0.026$), whereas the percentage of unmarked birds in late winter population increased (Table 2). The early spring population remained quite constant at 235 (7.0/km^2), 289 (8.6/km^2), 258 (7.6/km^2) and 240 (7.1/km^2) partridges during the four study years. Changes in population size from late winter to early spring were 41.5% in 1996, 61.9% in 1997, 43.9% in 1998 and 13.6% in 1999 with an overall decrease of 67.2% in the study period ($\chi^2 = 199.64$, df = 3, $P < 0.0001$).

The pair number showed small variations between years, whereas the percentage of pairs with at least one individual unmarked (i.e. born in the wild) increased noticeably during the study period; the number of unpaired partridges remained very variable during the four years (Table 3).

Brood number and percentage of successfully reproducing pairs

In the study area, we detected 47 broods in 1996 (1.4/km^2), 57 in 1997(1.7/km^2), 59 in 1998 (1.8/km^2) and 57 in 1999 (1.7/km^2) leading to a percentage of successfully reproducing pairs of 40.2, 45.6, 46.8 and 47.5%, respectively. The differences between years were not significant ($\chi^2 = 1.59$, df = 3, $P = 0.661$).

Brood size and chick survival rate

During the whole study period, the average brood size (± 1SE) was 6.9 (± 0.19; range: 1-16, N = 270, age class pooled). It increased from 5.9 in 1996 (± 0.31; range: 1-10, N = 58) to 6.4 in 1997 (± 0.31; range: 1-14, N = 85), to 7.5 in 1998 (± 0.57; range: 1-16, N = 49) and to 7.8 in 1999 (± 0.32; range: 2-15, N = 78). The precision of the mean ranged from 0.041 to 0.076. The differences between years were significant ($F_{3,266} = 6.17$, $P < 0.0001$). In particular, the average brood sizes in 1996 and 1997 were significantly lower than those from 1998 and 1999 ($P < 0.05$).

During the whole study period, brood size decreased significantly from hatching up to 60 days old (precision of the mean: 0.044-0.090). In particular, the decrease was significant between the first three and the last two age classes ($P < 0.01$; Table 4). In each study year, we recorded significant decreases in average brood size from hatching up to 30 days old (Table 5). The variation in the average brood size between years was significant only for broods > 30 days old ($F_{3, 103} = 3.81$, $P = 0.006$). Precision of the mean exceeded the critical value of 0.1

Table 5. Number (N) and mean brood size (± 1 SE) of the reintroduced population of red-legged partridges according to age class from hatching (0) to the age of > 30 days old for the years 1996-1999.

Age class	1996 N	1996 Mean	1997 N	1997 Mean	1998 N	1998 Mean	1999 N	1999 Mean
0	14	9.8 (0.88)	14	9.8 (0.88)	14	9.8 (0.88)	14	9.8 (0.88)
≤ 30	18	5.9 (0.68)	14	7.9 (0.72)	34	8.3 (0.67)	43	8.1 (0.37)
> 30	20	5.4 (0.41)	47	5.7 (0.40)	13	5.1 (0.98)	27	7.3 (0.56)
		F = 12.47		F = 12.36		F = 5.58		F = 3.66
		P < 0.0001		P < 0.0001		P = 0.006		P = 0.030

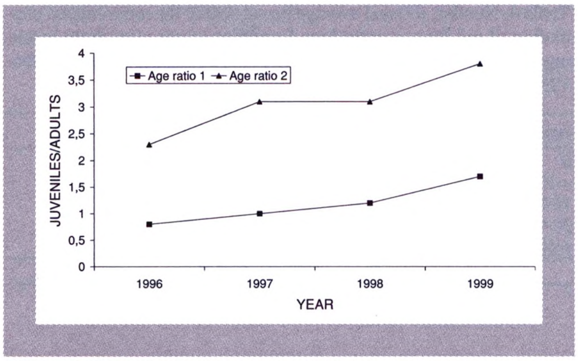

Figure 2. Age ratio of the reintroduced population of red-legged partridges for the years 1996-1999. Age ratio 1 is the number of young in summer to adults in spring, and age ratio 2 is the number of young in summer to adults in summer.

in only two cases: for broods < 30 days old in 1996 and for broods > 30 days old in 1998.

Chick survival rate (CSR) from hatching up to 60 days old was 60.2% during the whole study period and the CSR up to 30 days old was 55.1% in 1996, 58.2% in 1997, 52.0% in 1998 and 74.5% in 1999.

Age ratios

The total estimated number of juveniles in late summer in the study area was 188 (5.6/km^2) in 1996, 302 (8.9/km^2) in 1997, 307 (9.1/km^2) in 1998 and 410 (12.1/km^2) in 1999. The proportion of juveniles in the population increased from 1996 to 1999 (Fig. 2). The ratio of juvenile to adult numbers in spring was significantly different between 1996 and 1998 (test of equality of proportions: $P < 0.05$), between 1996 and 1999 ($P < 0.01$) and between 1997 and 1999 ($P < 0.01$). No significant differences were detected between the ratios of juveniles to the numbers of adults during summer in the different study years.

Adult losses, population growth rate and winter losses

Losses of adult red-legged partridges from early spring to late summer, i.e. during the breeding season, amounted to 66.0% in 1996, 65.7% in 1997, 61.6% in 1998 and 55.0% in 1999; and the decrease was significant (χ^2 = 8.28, df = 3, P = 0.040). Population growth rate from spring to late summer increased during the study period and was 14.0% in 1996, 38.7% in 1997, 57.4% in 1998 and 115.8% in 1999. Over-winter losses reached 32.1% in the winter of 1996/97, 66.1% in 1997/98 and 40.9% in 1998/99, so the differences between winters were significant (χ^2 = 87.94, df = 3, $P < 0.0001$).

Discussion

Beck et al. (1994) reported that only 11% (seven of 65) of bird reintroduction projects worldwide have been successful, and none of these involved Galliform species. Our reintroduction cannot be classified as successful on the basis of the very conservative criteria adopted by Beck et al. (1994), but the reintroduced population of red-legged partridge reached breeding densities and reproductive performances comparable to those reported for other populations in Europe. Moreover, some parameters improved during the study period.

The results of our present research are difficult to compare with those obtained in other studies because of the lack of detailed investigations into population dynamics of wild red-legged partridge within the European range. However, several studies carried out in Great Britain, France, Italy and on the Iberian Peninsula focused on estimating some important demographic parameters of the populations (see for example Potts 1980, Green 1983, 1984, Ricci 1985, Meriggi, Saino, Montagna & Zacchetti 1992, Borralho, Rego & Vaz Pinto 1997, Leonard & Reitz 1998).

The marked decrease in the late winter population from the third study year was probably due to the stop of summer releases in 1997 and coincided with the increase in the proportion of wild partridges in the population. This hypothesis is consistent with the decrease in the winter covey size that, during the last two winters, was comparable with that of wild populations (e.g. Green 1983; from 4.4 to 8.7 birds/covey in Great Britain). Moreover, releases had the effect of reducing the wild part of the reintroduced population, in particular in the following spring, possibly via increased dispersal of young born in the previous summer that survived the winter. In fact, together with the decrease of late winter population, changes in population size from late winter to early spring also decreased from 41.5 to 13.6% with the effect of stabilising the breeding population in spring.

Pair density in our study area slowly increased from the first to the second year and remained stable thereafter. The observed pair density (on average 3.6 pairs/km^2) was at low-medium levels if compared to those found in other European study areas (Ricci 1985, Meriggi et al. 1992, Leonard & Reitz 1998, Peiro & Blanc 1998, Ranoux 1998). The densities observed in Great Britain in the 1980s were markedly greater (Green 1983, Rands 1986).

The percentage of successfully reproducing pairs was high compared to the values recorded in other European study areas (Potts 1980, Meriggi et al. 1992, Leonard & Reitz 1998). The increase of successfully reproducing pairs in our study area may be due to both the decrease in predator density, the increase in the wild part of the population and to the more efficient nesting experience acquired by the released birds. Presumably, chicks produced by reared pairs breed themselves in the subsequent year and are in effect wild, with higher production rate and a greater ability to avoid predation than their reared parents. Differences in nesting success between wild and hand-reared birds were found in pheasants and grey partridges *Perdix perdix*, and may likely also occur in red-legged partridges (Hill & Robertson 1988, Putaala & Hissa 1998).

Average brood size increased from the first to the fourth study year, and this should be an indication of an increased breeding capability of the population in relation to the higher numbers of wild pairs, but predator control may also have influenced chick survival (Potts 1980). In our study area, the increase in the average brood size seems mainly related to the increase of chick survival rate, in particular in the first month of life. The average brood size recorded is comparable with those obtained in other European studies (Potts 1980, Lucio 1990, Meriggi et al. 1992, Carvalho et al. 1998). However, chick mortality appears to be very low compared to the values usually reported in the literature (Potts 1980, Green 1984, Leonard & Reitz 1998).

The ratio of young in summer over the number of adults both in summer and in spring increased constantly from 1996 to 1999. Age ratio in summer should be an index of good population productivity; in particular, if our data are compared to those collected in France and Spain, both by direct observations and from bag records (Coles 1976, Treussier & Fouquet 1978, Pepin 1981, Ruela 1981, Pepin, Cargnelutti & Mathon 1985, Peiro & Seva 1993, Nadal, Nadal & Rodriguez-Teijeiro 1996, Carvalho et al. 1998). Higher age ratios than ours were found only in the French region Pays de Loire (Treussier & Fouquet 1978) and in the Spanish Toledo province (Millas 1980), but these values refer to the 1970s and are not topical.

The age ratio calculated over the number of adults in summer is commonly used as a productivity index and to assess the sustainable yield, although it should be considered with caution because it might depend on several factors negative for the population (Caughley 1974). A high age ratio in summer may indicate a growing population, but it may also indicate a compensation of various and dramatic mortality factors to which the population is subjected. Furthermore, a high age ratio in summer could result from high adult mortality during the breeding season. More useful can be the ratio of the young present in summer over the number of adults in spring, i.e. before the start of the breeding season. Unfortunately, this ratio is rarely estimated, and it is therefore impossible to make extended comparisons. Our population showed an increasing number of young per adult and per pair in spring from 1996 to 1999 (0.8-1.7 young/adult and 1.6-3.4 young/pair) with significant differences between the former two and the latter two years. These values are in agreement with those found in northern Italy and in Portugal for wild populations (Meriggi & Prigioni 1985, Borralho et al. 1997).

Adult mortality during the breeding period (April - August), though in decrease during the study period, can be considered as the main negative factor acting and limiting the reintroduced population, whereas within the European range of the species, the losses of adult individuals are not an important mortality factor that can affect population dynamics (Ricci, Mathon, Garcia, Esteve & Berger 1989, Peiro & Seva 1995, Léonard & Reitz 1998). Adult losses during the breeding period may mainly be due to predation, acting, in particular, on nesting females and on non-breeding individuals, and to the dispersal of non-paired males and females (Potts 1980, Green 1983, Pépin, Cargnelutti & Mathon 1985). As in other monogamous Galliforme species, red-legged partridges seem to show a negative relation between brood production rate and spring-summer adult mortality; so that adult losses would be related to the breeding failure (Potts 1980).

The growth rate from spring to summer of the reintroduced population was markedly variable and increased during the study period. It seems to be strongly influenced by the brood production rate, by the average brood size and by the adult survival. Over-winter losses showed a high variability mainly depending on climatic factors, which were particularly severe in the second winter.

Changes in partridge populations are strictly related to some demographic parameters like brood production rate and chick survival that in turn are affected by habitat, predator impact and climate (Potts 1980, 1986). Other parameters, such as adult survival and over-winter losses, are of some importance only under particular circumstances. Our population showed a moderate improvement in the overall productivity, which mainly was related to increased production of youngs and to decreased adult mortality. The improvement in breeding performance occurred especially after the second study year, when the releases of reared birds stopped. Consequently, for the reintroduction success it seems important to stop releases after few years and in particular when the breeding density is stable and carrying capacity is reached. The prosecution of releases of farm-reared birds would maintain the domestic portion of the population with consequent losses of breeding efficiency (Dowell 1992). Moreover, habitat suitability of the reintroduction areas and management actions used and aimed at sustaining the population, such as predator control, food supply and hunting delay, can increase success probability. Our study demonstrated that reintroductions in suitable areas can effectively re-establish self-sustaining populations of red-legged partridges in the wild, thus preventing population fragmentation and species decline within the European range. Also restocking of over-exploited populations, carried out following the same criteria of reintroductions, can enhance density and productivity, provided that hunting is stopped.

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References

Aebischer, N.J. & Lucio, A.J. 1996: Red-legged Partridge Alectoris rufa. - In: Hagemeijer W.J.M. & Blair M.J. (Eds.); The EBCC Atlas of European Breeding Birds. Their distribution and abundance. European Bird Census Council, T & A D Poyser, London, pp. 208-209.

Aebischer, N.J. & Potts, G.R. 1994: Red-legged Partridge Alectoris rufa. - In: Tucker, G.M. & Heath, M.F. (Eds.); Birds in Europe, their conservation status. Birdlife Conservation Series No. 3, BirdLife International, Cambridge, pp. 214-215.

Alkon, P.U. 1982: Estimating the age of juvenile chukars. - Journal of Wildlife Management 46: 777-781.

Baccetti, N. 1996: Apelle Dei. - Scritti di ornitologia senese. - Memorie Accademia dei Fisiocritici 6:1-326. (In Italian).

Beck, B.B., Rapaport, L.G., Stanley Price, M.R. & Wilson, A.C. 1994: Reintroduction of captive-born animals. - In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.); Creative Conservation. Interactive management of wild and captive animals. Chapman & Cole, London, pp. 265-286.

Blondel, J. 1969: Méthodes de dénombrement des populations d'oiseaux. - In: Lamotte, M. & Bourlière, F. (Eds.); Problèmes d'écologie: l'échantillonage des peuplements animaux des milieux terrestres. Masson, Paris, pp. 97-151. (In French).

Borralho, R., Carvalho, S., Rego, F. & Vaz Pinto, P. 1999: Habitat correlates of red-legged partridge Alectoris rufa breeding density on Mediterranean farmland. - Revue d'Écologie (La Terre et la Vie) 54: 59-69.

Borralho, R., Rego, F. & Vaz Pinto, P. 1997: Demographic trends of red-legged partridges (Alectoris rufa) in southern Portugal after implementation of management actions. - Gibier Faune Sauvage, Game and Wildlife 14: 585-599.

Brun, J.C. & Aubineau, J. 1989: La reconstitution des populations de perdrix rouges (Alectoris rufa) et grises (Perdix perdix) a l'aide d'oiseaux d'èlevage. - Gibier Faune Sauvage 6: 205-223. (In French).

Carvalho, J., Castro-Pereira, D., Capelo, M. & Borralho, R. 1998: Red-legged partridge (Alectoris rufa) restocking programs: their success and implications on the breeding population. - Gibier Faune Sauvage, Game and Wildlife 15: 465-474.

Caughley, G. 1974: Interpretation of age ratios. - Journal of Wildlife Management 38: 557-562.

Coles, C. 1976: Spanish Partridges. Age grouping and sexing. - The Game Conservancy Annual Review of 1976, 8: 82-84.

Dowell, S.D. 1992: Problems and pitfalls of gamebird reintroduction and restocking: an overview. - Gibier Faune Sauvage 9: 773-780.

Fasola, M., Prigioni, C., Barbieri, F. & Meriggi, A. 1985: Census of Corvidae by winter counts of nests. - In: Taylor, K. (Ed.); Bird census and atlas studies. - VII International Conference Bird Census and Atlas work, British Trust for Ornithology, Tring, p. 141.

Foschi, U.F., Bulgarini, F., Cignini, B., Melletti, M., Pizzari, T. & Visentin, M. 1996: Catalogo della collezione ornitologica 'Arrigoni degli Oddi' del Museo Civico di Zoologia di Roma. - Ricerche di Biologia della Selvaggina 97: 1-311. (In Italian).

Gibbons, D.W., Hill, D. & Sutherland, W.J. 1996: Birds. - In: Sutherland, W.J. (Ed.); Ecological Census Techniques. A handbook. Cambridge University Press, Cambridge, pp. 227-259.

Gortazar, C., Villafuerte, R. & Martin, M. 2000: Success of traditional restocking of red-legged partridge for hunting purposes in areas of low density of northeast Spain Aragon. - Zeitschrift für Jagdwissenschaft 46: 23-30.

Green, R.E. 1983: Spring dispersal and agonistic behaviour of the Red-legged partridge (Alectoris rufa). - Journal of Zoology, London, 201: 541-555.

Green, R.E. 1984: The feeding ecology and survival of partridge chicks (Alectoris rufa and Perdix perdix) on arable farmland in East Anglia. - Journal of Applied Ecology 21: 817-830.

Havet, P. & Biadi, F. 1990: Réintroductions et soutiens de populations d'espèces de petit gibier. - Revue d'Écologie (La Terre et la Vie), Suppl. 5: 261-289. (In French).

Hill, D.A. & Robertson, P. 1988: Breeding success of wild and hand reared ring-necked pheasants. - Journal of Wildlife Management 52: 446-450.

Kleiman, D.G., Stanley Price, M.R. & Beck, B.B. 1994: Criteria for reintroductions. - In: Olney, P.J.S., Mace, G.M. & Feistner, A.T.C. (Eds.); Creative Conservation. Interactive management of wild and captive animals. Chapman & Cole, London, pp. 287-303.

Léonard, Y. & Reitz, F. 1998: Caractèristique de la reproduction de la perdrix rouge (Alectoris rufa) dans le centre de la France. - Gibier Faune Sauvage, Game and Wildlife 15: 747-757. (In French).

Lucio, A.J. 1990: Influencia de las condiciones climaticas en la productividad de la perdiz roja (Alectoris rufa). - Ardeola 37: 207-218. (In Spanish).

Massi, A. 1990: La collezione ornitologica Paolucci. - Quaderni del Museo di Storia Naturale di Livorno 11: 25-86. (In Italian).

Meriggi, A. & Prigioni, C. 1985: Productivité d'une population de Perdrix grise (Perdix perdix) dans les Apennins de l'Italie du Nord et répartition du milieu avec la perdrix rouge (Alectoris rufa). - Transactions XVIIth IUGB Congress, pp. 351-358. (In French).

Meriggi, A., Saino, N., Montagna, D. & Zacchetti, D. 1992: Influence of habitat on density and breeding success of grey and red-legged partridges. - Bollettino di Zoologia 59: 289-295.

Millan, J., Gortazar, C. & Villafuerte, R. 2001: Marked differences in the splanchnometry of farm-bred and wild red-legged partridges (Alectoris rufa L.). - Poultry Science 80: 972-975.

Millan, J., Gortazar, C., Tizzani, P. & Buenestado, F.J. 2002: Do helminths increase the vulnerability of released pheasants to fox predation? - Journal of Helminthology 76: 1-6.

Millas, I. 1980: Introduccion al estudio de la dinamica de poblaciones de perdrices en territorios de caza de la provincia de Toledo. - 3e Réunion du groupe de travail sur les perdrix du genre Alectoris. Toulouse, France, 31 pp. (In Spanish).

Nadal, J., Nadal, J. & Rodriguez-Teijeiro, J.D. 1996: Red-legged partridge (Alectoris rufa) age and sex ratios in declining populations in Huesca (Spain) applied to management. - Revue d'Ecologie (La Terre et la Vie) 51: 243-257.

Peiro, V. & Blanc, C.P. 1998: Système d'information géographique et gestion de la perdrix rouge (Alectoris rufa) dans le plaine viticole de l'Hérault (France). - Gibier Faune Sauvage, Game and Wildlife 15: 355-378. (In French).

Peiro, V. & Seva, E. 1993: Relaciones de sexos y edades y cronología de eclosiones de la perdiz roja (Alectoris rufa) en el sur de la provincia de Alicante. - Doñana Acta Vertebrata 20: 5-18. (In Spanish).

Peiro, V. & Seva, E. 1995: Succès reproducteur et survie des perdrix rouges (Alectoris rufa) d'une population de la Province d'Alicante (Espagne). - Gibier Faune Sauvage, Game and Wildlife 12: 183-195. (In French).

Pépin, D. 1981: Données démographiques obtenues à partir de l'examen d'ailes de perdrix rouges Alectoris rufa L. abattues à la chasse dans la région de Béziers (Hérault). - Acta Oecologica 2: 215-226. (In French).

Pépin, D. 1983: Utilisation et valeur de diverses méthodes d'estimation de la densité de la Perdrix rouge (Alectoris rufa) au printemps. - Transactions XV Congreso International Fauna Cinegenetica y Silvestre, Trujillo, pp. 725-735. (In French).

Pépin, D., Cargnelutti, B. & Mathon, J.F. 1985: Démographie de la Perdrix rouge (Alectoris rufa). - Acta Oecologica 6: 31-46. (In French).

Potts, G.R. 1980. The Effects of Modern Agriculture, Nest Predation and Game Management on the Population Ecology of Partridges (Perdix perdix and Alectoris rufa). - Advances in Ecological Research 11: 1-79.

Potts, G.R 1986: The partridge. Pesticide, Predation and Conservation. - Collins, London, 274 pp.

Potts, G.R 1989: The impact of releasing hybrid partridges on wild red-legged populations. - Game Conservancy Review of 1989, pp. 81-85.

Potts, G.R. & Aebischer, N.J. 1995: Population dynamics of the Grey Partridge Perdix perdix 1793-1993: monitoring, modelling and management. - Ibis 137: 29-37.

Putaala, A. & Hissa, R. 1998. Breeding dispersal and demography of wild and hand-reared grey partridges Perdix perdix in Finland. - Wildlife Biology 4: 137-145.

Rands, M.R.W. 1986: Effect of hedgerow characteristics on partridge breeding densities. - Journal of Applied Ecology 23: 479-487.

Rands, M.R.W. 1992: The conservation status and priorities for threatened partridges, francolins and quails of the world. - Gibier Faune Sauvage 9: 493-502.

Ranoux, F. 1998: Modèles de prédiction des densités printanières de perdrix grises (Perdix perdix) et rouges (Alectoris rufa) dans le massif central. - Gibier Faune Sauvage, Game and Wildlife 15: 339-354. (In French).

Ricci, J.C. 1985: Influence de l'organisation sociale et de la densité sur les relations spatiales chez la perdrix rouge. Conséquences démographiques et adaptatives. - Revue d'Ecologie (La Terre et la Vie) 40: 53-84. (In French).

Ricci, J.C., Mathon, J.F., Garcia, A., Esteve, J.P. & Berger, F. 1989: Méthode de capture, de marquage et de suivi par radiopistage des perdrix rouges dans le midi méditerranéen: Bilan de programme (1986-1988). - Bulletin Mensuel ONC 140: 15-24. (In French).

Ruela, L. 1981: Red-legged partridge (Alectoris rufa). Determination of partridges age in Portugal. - Transactions XV Congreso International Fauna Cinegetica y Silvestre, Trujillo, pp. 797-810.

Treussier, M. & Fouquet, M. 1978: Contribution à l'étude de la Perdrix rouge Alectoris rufa L., par l'analyse des mesures d'ailes d'oiseaux tués à la chasse. - Bulletin Mensuel ONC 8: 38-57. (In French).

Tucker, G.M. & Heath, M.F. 1994: Birds in Europe, their conservation status. - Birdlife Conservation Series No. 3, BirdLife International, Cambridge, 600 pp.

UNEP-WCMC 2001: Animals of the World Database. http://www.unep-wcmc.org/species/02-037 Merigianimals/animal_redlist.

Von Schantz, T. & Liberg, O. 1982: Censusing numbers of medium-sized nocturnal mammals in open landscape. - Transactions XIV Congress IUGB, Dublin, Ireland, pp. 409-413.