Survival and morphometrics of radiocollared wild and reared red-legged partridges *Alectoris rufa* in Pisa province (Tuscany, central Italy)

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Abstract – Small populations of red-legged partridge are present in Pisa province (Tuscany, central Italy) as a result of reintroductions carried out for hunting purposes. This two-years research aimed to the evaluation of some survival and behaviour parameters of wild and just released reared red-legged partridge through the use of radio-tracking. Wild partridges were studied in two protected areas; in February 2011, 26 individuals were captured and fitted with radiocollars. Reared partridges were released in July 2011, using acclimatization birdcages, in other three protected areas. In this case, 30 subjects were tagged with radiocollars. Wild partridges showed higher survival rate than reared partridges. Among the latter, dead individuals had higher weight and wing loading than alive birds. This effect was not observed for wild partridges. Reared partridges were less selective in habitat choice and they seemed to perform larger movements than wild individuals.

Key-words: *Alectoris rufa*, radio-tracking, mortality, biometry, Pisa province.

INTRODUCTION

Red-legged partridge *Alectoris rufa* (Linnaeus, 1758) shows an unfavourable conservation status in Europe (BirdLife International 2004) and in this context also the Italian populations are strongly decreasing (Brichetti & Fracasso 2004, Spanò 2010). Therefore a radio-tracking investigation has been set up on this species to obtain useful information for a management project of red-legged partridge in Pisa province (Tuscany, central Italy).

The radio-tracking investigation has been performed on both wild partridges and just released reared partridges in protected areas of Pisa province with the aims of recording the survival rate, detecting the cause of death, measuring the home range and monitoring the use of habitat in the two groups of partridges.

The release of the birds followed the implementation of environmental improvements addressed to this species. In this paper we report the survival rate, causes of death and use of habitat for both groups.

MATERIAL AND METHODS

The investigation was performed in five no-hunting areas (ZRV Il Castellare, ZRV Calci, ZRC Villamagna, ZRC Volterra, ZRV Guardistallo) of Pisa province, Tuscany, central Italy (Fig. 1).

In February 2011, 26 wild partridges were captured, collared, released and monitored in ZRV Il Castellare and in ZRV Calci. In ZRV Calci 9 wild partridges (5 males and 4 females) were captured while in ZRV Il Castellare 17 birds (12 males and 5 females) were captured (Tab. 1).

The partridges were caught by both elevated traps and by ground traps (Fig. 2) using corn as bait.

In July 2011, 300 reared partridges (90-days old) were released using small birdcages of acclimatization in ZRC Villamagna, ZRC Volterra and ZRV Guardistallo; 30 reared birds (10 for each area) were fitted with radio collars (Bio-track VHF necklace tags).

Morphometric analysis

Every radio tagged partridge was measured to obtain the

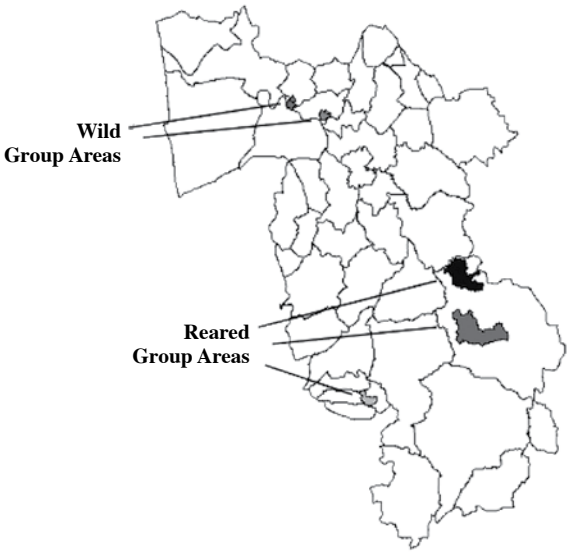

Figure 1. Study Areas. The location of the study areas in the Pisa province (Tuscany) is shown.

following morphometric data: weight (Electronic Libra, precision ± 1g), tarsus length (calibre), tarsus diameter (calibre), wing length (ruler) and tail length (ruler).

The relationship weight/length was used to have an index of the wing loading and then the flight efficiency in the analysed subjects. The wing loading adversely affects the angle and speed of fledging from the ground (Petrini *et al*. 1995, Venturato *et al*. 1999). When the index value increases, flee efficiency decreases.

The morphometric measurements were used to assess any difference between the two groups of radiocollared partridges and between dead or alive individuals at 14th weeks after release. After the normality verification of the biometric variables (Shapiro Wilk test; Shapiro & Wilk 1965), we used F-test and t-test to compare variances and means (Pépin 1985). In any comparison, if the value of F-test did not exceed significance level, t-test was calculated (Fowler & Cohen 1995). The level of significance used was $P < 0.05$.

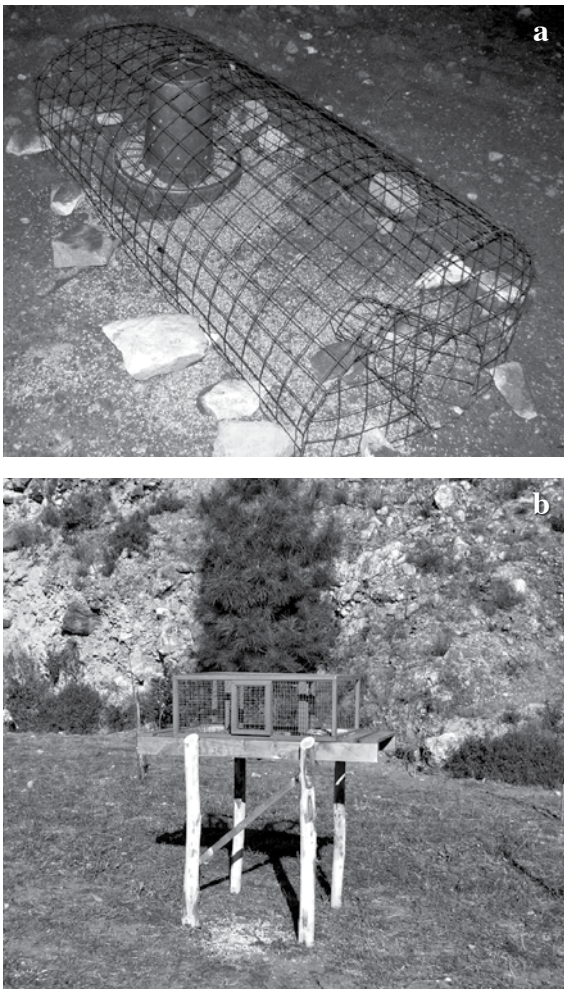

Figure 2. Example of trap on the ground (**a**) and rack trap (**b**).

Radiotracking

Radio collars were equipped with a VHF transmitter with a power range of 1.5-2 km. This transmitter was chosen as compromise between weight and duration (12 months). The average weight of the used radio with collar is approximately 12 grams. This is less than 3% of animal body

Table 1. Number of radiocollared partridges and sex ratio in each study area.

	Protected area	Area (ha)	N. Radiocollared partridges	Males	Females
Captured wild partridges (WP)	ZRV Il Castellare	173	17	12	5
	ZRV Calci	163	9	5	4
Released reared partridges (RP)	ZRV Guardistallo	331	10	0	10
	ZRC Villamagna	1404	10	0	10
	ZRC Volterra	2263	10	0	10

weight and so the radio should not affect the survival of partridges (Marcstrom *et al*. 1989, Warner & Etter 1993, Peréz *et al*. 2004). The used instruments are the following: 56 radio collars TW-3 model, produced by Biotrack; 3 YAGI directional antennas; 1 SIGMA omnidirectional antenna with a device to be applied troughs magnet on the car's roof; 3 receivers YAESU model.

The partridges were followed three times a week in the first month after release and twice a week in the others months. Time, weather condition, frequency of the radio collar and environmental characteristics of location fix were recorded on daily tracking form.

Location fixes of partridges with all related data were also reported in geo-referenced digital cartography (Quantum GIS).

Land use and habitat preferences

In the five investigated areas, detailed analysis of land use was carried out by: subdivision of the territory, based on aerial photographs (scale 1:10000), by using GIS software (QuantumGIS); direct inspections of the patches to categorize them according to CORINE Land Cover (CLC) codes. Environmental preferences of radio-collared subjects were analysed by associating their geographical location to the categories of Land Use.

In particular, it was considered the first level of CLC Land Use:

1) urban areas;
2) agricultural areas;
3) wooded areas.

To highlight possible habitat preferences in each study area, a contingency analysis was carried out based on the evaluation of the observed vs. expected frequencies for each of the three categories of Land Use (Fowler & Cohen 1995). The expected frequencies were calculated as total number of fixes for the study area multiplied by the proportion of the area included in each category (urban zones, agricultural zones, wooded zones). More substantial deviations from expected frequencies indicated which environment is preferred or avoided.

Survival and mortality

The captured wild individuals had been followed for 35 weeks and the reared ones for 14 weeks.

For survival analysis it was chosen the product-limit estimation's method proposed by Kaplan and Meier (Kaplan & Meier 1958) and taken up by Pollock (Pollok *et al*.1989a, 1989b) to fit telemetry studies (Petrini 1995). This is a non parametric method so it is not necessary to define a parametric survival curve or periods in which survival is constant. The method allows to follow the time course of killed individuals and it does not delete, from the analysis, animals who have strayed too far or whose collars were broken. It also allows for comparisons between different experimental groups using the log-rank test, a non-parametric test used, to compare the survival distributions of two samples (Savage 1956, Kalbfleisch & Prentice 1980).

RESULTS

Morphometric analysis

In the wild group, measures of tarsus diameter ($F_{16,8} = 7,82$ $P < 0.05$) and weight ($F_{16,8} = 4,96$ $P < 0.05$) were significantly higher in males partridges than in females (Table 2). Therefore, to avoid a possible bias in data analysis, only individuals of the same sex were compared.

Also the comparison between animals of Reared Group and Wild Group showed several differences but the t- test showed that none was significant (Table 3).

In the Wild Group there were not significant differences between live or dead animals (Table 5). In Reared Group, the values of weight ($F_{11,17} = 3,72$ $P < 0.05$) and the index of wing loading ($F_{11,17} = 4,33$ $P < 0.05$) were signifi-

Table 2. Mean (± SD) biometric measures and index of flight efficiency in males and females of wild partridges (WP). Statistical results (F-test and t-test) for the comparisons between two sexes is also reported *significant test with $P < 0.05$.

WP		**Tarsus diameter** (cm)	**Tarsus lenght** (cm)	**Wing lenght** (cm)	**Weigth** (g)	**Tail lenght** (cm)	**Index of wing loading**
Males (n: 17)	Mean	0.73	5.62	23.02	508	11.14	22.04
	SD	0.14	0.21	0.8	73.76	0.71	2.92
Females (n: 9)	Mean	0.64	5.34	22.24	426	10.56	19.19
	SD	0.05	0.14	0.79	34.07	0.46	1.94
F		**7.82***	2.29	1.09	**4.96***	2.51	2.4
t		-	0.001	0.03	-	0.04	0.02

Table 3. Mean (± SD) biometric measures and index of flight efficiency in females of reared partridges (RP) and wild partridges (WP). Statistical results (F-test and t-test) for the comparisons between the two groups is also reported. *significant test with P < 0.05.

		Tarsus diameter (cm)	**Tarsus lenght** (cm)	**Wing lenght** (cm)	**Weigth** (g)	**Tail lenght** (cm)	**Index of wing loading**
RP (n: 30)	Mean	0.68	5.6	21.32	384	10.27	18.04
	SD	0.06	0.22	1.47	31.25	0.82	1.23
WP (n: 9)	Mean	0.64	5.34	22.24	426	10.56	19.19
	SD	0.05	0.14	0.79	34.07	0.46	1.94
F		**9.35***	2.56	**3.73***	1.09	**3.37***	**2.31***
t		-	0.002	-	0.001	-	-

Table 4. Mean (± SD) biometric measures and index of flight efficiency in alive or dead reared partridges (RP). Statistical results (F-test and t-test) for the comparisons between the two groups is also reported.*significative test with P < 0.05.

RP		**Tarsus diameter** (cm)	**Tarsus lenght** (cm)	**Wing lenght** (cm)	**Weigth** (g)	**Tail lenght** (cm)	**Index of wing loading**
Alive (n: 12)	Mean	0.67	5.61	21.5	378.33	10.58	17.64
	SD	0.06	0.19	1.58	55.73	0.63	2.49
Dead (n: 18)	Mean	0.69	5.6	21.19	381.11	10.06	18.01
	SD	0.06	0.26	1.07	27.12	0.89	1.28
F		1.16	1.66	1.21	**3.72***	1.95	**4.33***
t		0.643	0.831	0.585	-	0.083	-

Table 5. Average (± SD) biometric measures and index of flight efficiency in alive or dead wild partridges (WP). Statistical results (F-test and t-test) for the comparisons between the two groups is also reported.*significative test with P < 0.05.

WP		**Tarsus diameter** (cm)	**Tarsus lenght** (cm)	**Wing lenght** (cm)	**Weigth** (g)	**Tail lenght** (cm)	**Index of wing loading**
Alive (n: 12)	Mean	0.6	5.26	22.54	416	10.6	18.45
	SD	0.03	0.12	0.46	29.16	0.55	1.18
Dead (n: 4)	Mean	0.68	5.45	21.88	438.5	10.5	20.11
	SD	0.03	0.11	1.03	39.84	0.41	2.48
F		1	1.27	4.79	1.75	1.92	4.13
t		0.01	0.05	0.23	0.36	0.77	0.22

cantly higher in dead partridges than in live partridges (Table 4).

Land use and habitat choice

In the areas of ZRC Volterra, ZRC Villamagna and ZRV Guardistallo agricultural land is predominant, whereas the areas of ZRV Il Castellare and ZRV Calci are mostly represented by the urbanized zones (Table 6). ZRV Castellare and ZRV Calci are strongly characterized by the presence of stone quarries that contribute to the percentage of urbanized zones.

The only significant habitat preference of radiocollared individuals was observed in the ZRV Calci and ZRV Castellare. In ZRV Calci wild partridges preferred urban and wooded zones; in ZRV Castellare wild partridges preferred urban and agricultural zones (Tables 7). Reared partridges did not show any preference.

Survival and mortality

Intensive monitoring, in the first month of release, allowed the rescue of the carcasses and collars and to attribute the correct causes of death (Fig. 3). The mortality was mainly (65%) due to terrestrial predators in particular carnivores. This was confirmed in both Reared group ($\chi^2_3 = 22{,}67$, df = 4, P < 0.01) and Wild Group ($\chi^2_2 = 16{,}31$, $df = 4$, P < 0.01) (Fig. 4).

Table 6. Percentage distribution of the categories of land use in the study areas.

	Urban zone (%)	**Agricultural zone** (%)	**Wooded zone** (%)
ZRV Il Castellare	43.8	37.2	18.9
ZRV Calci	21.5	30.4	48.1
ZRC Volterra	5.6	73.2	21.2
ZRC Villamagna	3.6	77.1	18.9
ZRV Guardistallo	8.2	55.4	36.4

Table 7. Observed vs. expected frequencies for the environmental choice of red-legged partridge. Individual component of $\chi 2$ test1 is also reported.*significative test with $P < 0.01$.

	Urban zone		**Agricultural zone**		**Wooded zone**	
	Observed	Expected	Observed	Expected	Observed	Expected
ZRV Calci	116	65	130	92	56	145
χ^2	**40.2***		15.9		**54.9***	
ZRV Il Castellare	238	165	66	140	73	71
χ^2	**32.2***		**39.3***		0.04	
ZRV Guardistallo	5	13	96	89	59	58
χ^2	5.03		0.61		0.01	
ZRC Villamagna	0	4	77	88	37	22
χ^2	4.1		1.35		1.08	
ZRC Volterra	5	4	37	48	23	14
χ^2	0.51		2.35		6.17	

[1] df = 8

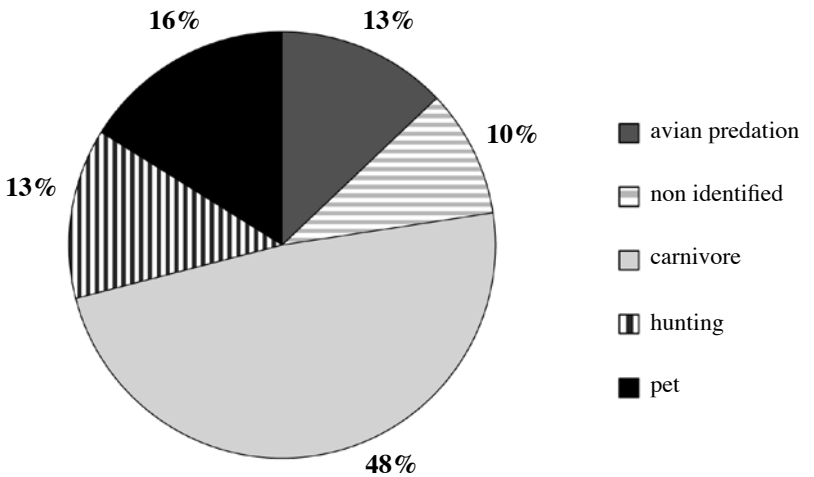

Figure 3. Percentages of the different causes of mortality in radiocollared partridges.

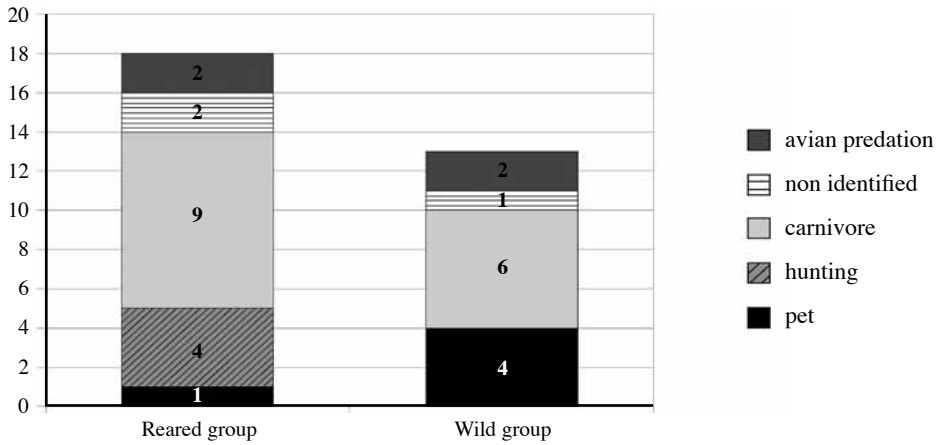

Figure 4. Causes of mortality in reared and in wild groups.

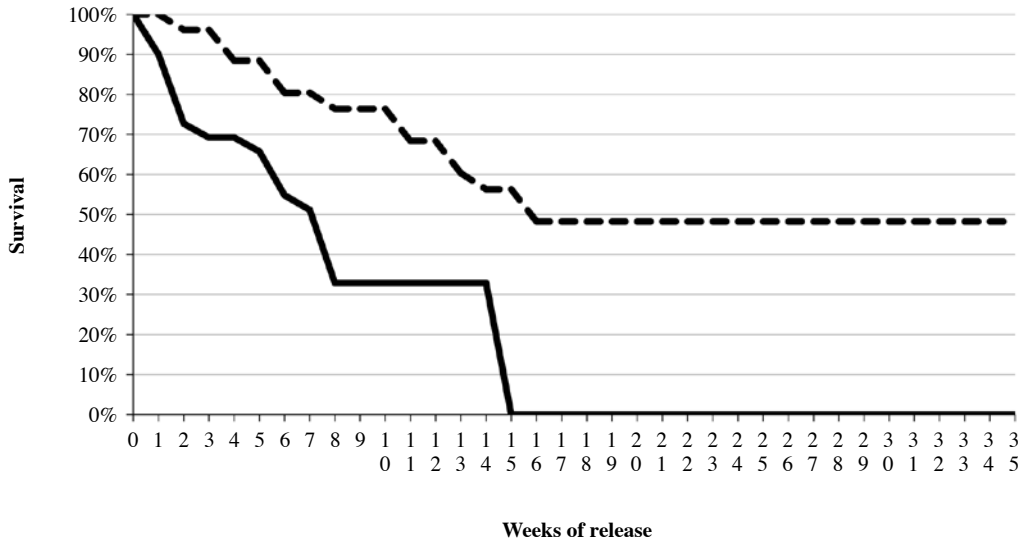

Figure 5. Survival (expressed as percentage of living individuals on the total of radiocollared partridges) trend in the two study groups of partridges (W.P.: Wild Partridges; R.P.: Reared Partridges).

The comparison of the survival of the two groups of partridges was statistically significant (Log-rank test, $\chi^2_1 = 24{,}99$ $P < 0.01$). The Wild Group showed a survival of 50% at 16 weeks. For the Reared Group the survival of 50% is already at 7 weeks (Fig. 5).

DISCUSSION

The analysis of the results allows us to highlight some discriminating factors that may have influenced mortality of partridges. The wild partridges had a better survival rate than the reared partridges. Moreover, the dead individuals among reared partridges had a higher weight and index of wing loading as compared to the survived ones. Significant differences for morphometrics between live or dead individuals were not observed among the captured wild partridges. This suggests that the morphological differences highlighted might have affected the lower survival of reared partridges.

The morphological differences added to the physiological characteristics and animal behaviour induced by captive breeding, can affect the social behaviours and the use of natural foods (Spanò *et al*. 1998). This was likely

reflected in the different habitat use recorded for the two groups of partridges. In fact, the wild ones showed a higher utilization of quarry land at the expense of agricultural environment whereas reared partridges showed no preference for particular types of environment and they seemed to frequent all areas equally.

The study shows that the mortality was mainly due to terrestrial predators in particular carnivores. The greater weight, in fact, could adversely affect the survival of a partridge reducing its ability to escape. In addition, as it often happens in rearing conditions, reared partridges could lose the antipredatory responsiveness (Bagliacca *et al*. 1999a, 1999b).

Although reared partridges were released in protected areas significantly wider than the areas where the captured wild partridges lived, hunting had a strong influence on the first (22%) and no effect on the latter: a possible symptom of greater mobility of reared individuals bringing them to cross more frequently the boundaries of protected areas. Further data analysis of home range may provide more precise information on this and other limiting factors on the survival and behaviour of this species. A more careful analysis of land use will enable us to detect more detailed habitat preferences in the study areas.

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REFERENCES

Bagliacca M., Profumo A. & Paci G., 1999a. Effetto della tecnica di allevamento sulla reattività "fear" delle starne (*Perdix perdix*). Atti Soc. ital. Sc. veter. 53: 435-436.

Bagliacca M., Profumo A. & Paci G., 1999b. Deposizione di starne (*Perdix perdix* L.) nate da genitori naturali a confronto con starne nate da incubazione artificiale. Riassunti IV Conv. naz. Biologi Selvaggina, Bologna: 73.

BirdLife International, 2004. Birds in Europe: population estimates, trends and conservation status. BirdLife Conservation Series No. 12, Cambridge.

Brichetti P. & Fracasso G., 2004. Ornitologia Italiana. Vol. 2 - Tetraonidae-Scolopacidae. A. Perdisa ed., Bologna.

Fowler J. & Cohen L., 1995. Statistics for Ornithologists. BTO Guides 22.

Kalbfleisch J. D. & Prentice L., 1980. The statistical analysis of failure data. John Wiley and Sons, New York.

Kaplan E. L. & Meier P., 1958. Non-parametric estimation from incomplete observations. J. Am. Statistical Ass. 53, No. 282.

Marcstrom V., Kenward R. E. & Karlbom M., 1989. Survival of ring- necked pheasants with backpacks, necklaces and leg bands. J. Wildl. Manage. 53: 808-810.

Pépin D., 1985. Morphological Characteristics and Sex Classification of Red-Legged Partridge. J. Wildl. Manage. 49: 228-237.

Peréz J.A., Alonso M.E., Gaudioso V.R., Olmedo J.A., Diez C. & Bartolomé D., 2004. Use of Radio-Tracking techniques to study a summer repopulation with Red-Legged Partridge (*Alectoris rufa*) chicks. Poultry Science 83: 882-888.

Petrini R., 1995. Il metodo Kaplan-Meier per l'analisi quantitativa della sopravvivenza degli animali in natura: applicazione ad uno studio sul fagiano. Suppl. Ric. Biol. Selvaggina 23: 177-183.

Petrini R., Papeschi A. & Dessì-Fulgheri F., 1995. Fattori che influenzano la predazione sul fagiano maschio. Suppl. Ric. Biol. Selvaggina 22: 711-717.

Pollock K. H., Winterstein S. R., Bunck C. M. & Curtis P. D., 1989a. Survival analysis in telemetry studies: the staggered entry design. J. Wildl. Manage. 53: 7-15.

Pollock K.H., Winterstein S.R. & Conroy M.J., 1989b. Estimation and analysis of survival distribution for radio-tagged animals. Biometrics 45: 99-109.

Savage I. R., 1956. Contributions of the theory of order statistics-the two sample case. Ann. Math. Stat. 27: 590-615.

Shapiro S. S. & Wilk M. B., 1965. Analysis of variance test for normality (complete samples). Biometrika 52: 591-611.

Spanò S., 2010. La Pernice rossa. Edizioni Il Piviere.

Spanò S., Meriggi A. & Simonetta A.M., 1998. Pernice rossa, Coturnice, Pernice sarda, Colino della Virginia, Quaglia e Fancolino. In: Principi e tecniche di gestione faunistico-venatoria. Ed Greentime, pp. 150-175.

Venturato E., Scarselli D., Petrini R. & Cavallini P., 1999. Sopravvivenza e riproduzione di fagiani (*Phasianus colchicus*) di allevamento immessi in natura: confronto preliminare tra giovani e adulti. Riassunti IV Conv. Naz. Biol. Selvaggina, pp. 62-63.

Warner R. E. & Etter S.L., 1983. Reproduction and survival of radio-marked hen ring-nacked pheasants in Ilinois. J. Manag. 47: 369-375.