Effects of necklace radio transmitters on survival and breeding success of red grouse Lagopus lagopus scoticus

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SHORT COMMUNICATION

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Effects of necklace radio transmitters on survival and breeding success of red grouse *Lagopus lagopus scoticus*

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The effects of necklace radio transmitters on survival and breeding success of red grouse *Lagopus lagopus scoticus* in southern and central Scotland during 1991-1994 were assessed. Recovery rates of birds with 15-g dummy radio transmitters did not differ from those of control birds marked with wing tags only. Clutch size and hatching success did not differ between female grouse equipped with functioning radio transmitters and an independent sample of control birds. It appears that necklace radio transmitters had no measurable effect on survival and breeding success of red grouse in our study areas, although the power of the statistical tests was low.

Key words: breeding success, Lagopus lagopus scoticus, necklace, radio transmitter, red grouse, survival, Scotland

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The effects of radio transmitters on gallinaceous birds are uncertain. Some researchers have reported that transmitters mounted on backpacks (Brander 1968) reduced survival and breeding success in galliforms (Erikstad 1979, Herzog 1979, Johnson & Berner 1980, Warner & Etter 1983), whereas others have found their effects to be minimal (Boag et al. 1973, Lance & Watson 1977, Hines & Zwickel 1985).

Radio transmitters mounted on ponchos (Amstrup 1980) or necklaces (Kenward 1987) are generally smaller, less restrictive, and quicker to fit than backpacks. However, the results of studies designed to examine the effects of poncho transmitters on galliforms have been equivocal. Whilst ruffed grouse *Bonasa umbellus* survived better with poncho radios than with backpack radios (Small & Rusch 1985), chukars *Alectoris chukar* either removed poncho radios or died within a few weeks (Slaugh et al. 1989). Furthermore, Marks & Marks (1987) reported that Columbian sharp-tailed grouse *Tympanuchus phasianellus columbianus* with leg bands survived better than grouse with radios on ponchos.

Recent studies on the effects of necklace radio transmitters have been more encouraging. Marcstrom et al. (1989) demonstrated that recovery rates of ring-necked pheasants *Phasianus colchicus* with dummy necklace radio transmitters did not differ from those of controls, whereas the recovery of pheasants with dummy backpacks was significantly lower. Similarly, in a study of black grouse *Tetrao tetrix*, 43% of males with necklace radios were recaptured after a year versus 41% of males marked with leg bands (Willebrand 1988). Finally, breeding season survival rates of necklace radio-marked male rock ptarmigan *Lagopus mutus* were not significantly lower than unmarked controls, whereas males with backpack radios had lower survival rates (Cotter & Gratto 1995).

Therefore, we investigated the effects of necklace radio transmitters on survival and breeding success of red grouse *Lagopus lagopus scoticus*, a small galliform of 600-800 g. We compared the survival of grouse fitted with dummy necklace transmitters to control grouse marked only with metal wing tags. We also compared the breeding success of female grouse fitted with functioning necklace transmitters to a control group of untagged grouse.

Methods

Effects of radio transmitters on the survival of red grouse were studied on a grouse moor near Langholm in southern Scotland. Grouse densities on the 10 km^2 study area, estimated from counts using trained pointing dogs, averaged 50 birds/km^2 in October 1993. Predators of grouse on the study area included red fox *Vulpes vulpes*, hen harrier *Circus cyaneus* and peregrine falcon *Falco peregrinus*.

We captured 151 grouse between 7 October and 20 November 1993. Grouse were caught at night in hand-held nets after dazzling with strong lights. All birds were weighed and measured (carpal to tip of third primary) for an index of body size and classified by age and sex (juvenile and adult, male and female) based on plumage characteristics (Hudson 1986). All birds were marked in the patagium of each wing with small, inconspicuous, numbered metal tags. Every other bird was also fitted with a dummy necklace radio transmitter. Dummy radios were cylindrical in shape measuring 38 x 16 x 16 mm and weighed 15 g. The radios included a 250-mm whip antenna and were attached by a soft cord which was passed around the neck of the bird and adjusted to the chosen circumference (Kenward 1987).

We subsequently captured 88 grouse between 14 and 22 March 1994, and 60 grouse between 3 and 9 October 1994 using the same methods. Of the 148 birds caught in March and October 1994, 31 had been marked during the previous autumn. To avoid bias in recapturing radio-marked birds, we always attempted to capture the grouse closest to the light.

We recovered marked grouse killed by predators during monthly systematic searches of 2 km^2 of the study area from October 1993 to March 1994, during a single systematic search of the entire study area in July 1994, and during the course of routine field work from October 1993 to September 1994. It is unlikely that all carcasses of dead grouse were found. The cause of death of all grouse was assigned where possible by examination of the carcass. Raptors normally plucked feathers and left an articulated skeleton with the sternum notched, whereas foxes usually chewed their prey so that broken bones and cut feathers were present (Jenkins et al. 1963, 1964, Hudson 1986, 1992). To avoid bias in recovering radio-marked birds, we only included the carcasses which retained their metal wing tags.

Effects of necklace radio transmitters on breeding success of red grouse were studied on two moors near Newtonmore in central Scotland. Grouse densities were similar to those in southern Scotland, and grouse were exposed to the same range of predators. In these sites we captured 30 female grouse during winter 1991-92, 1992-93, and 1993-94 using the same techniques as in southern Scotland. Each bird was fitted with a functioning necklace radio transmitter of identical size and weight to those used in the survival study. Clutch size and hatching success were recorded for each radio-marked female and compared with a control group of unmarked females for which data on breeding success was obtained during the same sampling period. Nests of the control birds were located using trained pointing dogs, marked with a bamboo cane placed 10 m from the nest site, and subsequently visited after chick hatch to determine hatching success.

We tested for differences between radio-marked and wing-tagged grouse in body weight and wing length using a 3-way ANOVA test which included mark type, age and sex as classifying factors. We used Chi-squared tests of independence (one-tailed) to test for differences in recovery rates of radio-marked and wing-tagged grouse. We tested for differences in breeding success between radio-marked and control grouse using a 3-way ANOVA test (one-tailed) which included mark type, year and study area as classifying factors.

For the one-tailed tests involving mark type, we calculated the power of being able to detect a difference between radio-marked and control grouse if a difference existed (see e.g. Sokal & Rohlf 1981). Power is the probability of rejecting the null hypothesis when it is false, and increases as the magnitude of the difference, $\underline{d}$, increases. In the absence of a mean/variance relationship (homoscedasticity), the power of a one-tailed test based on the normal distribution is calculated as $1-\Phi(\underline{t}_{0.1,\gamma}-\underline{d}/\underline{s}_{\underline{d}})$ if $\underline{d}$ is

Table 1. Morphometric characteristics of the 151 red grouse marked with either radio transmitters and wing tags, or wing tags only near Langholm in southern Scotland during October and November 1993.

Age	Sex	Type	n	Weight (g)		Wing length (mm)	
				$\bar{x}$	SE	$\bar{x}$	SE
Adult	Male	Radio	24	760	10	210	1
	Male	Wing	25	764	10	213	1
	Female	Radio	16	707	13	201	1
	Female	Wing	13	692	4	200	1
Juvenile	Male	Radio	14	731	15	208	2
	Male	Wing	19	716	8	206	2
	Female	Radio	19	648	17	201	1
	Female	Wing	21	643	8	195	1

expected to be positive, or $\Phi(\underline{t}_{0.1,\gamma}-\underline{d}/\underline{s}_{\underline{d}})$ if $\underline{d}$ is expected to be negative, where γ is the number of degrees of freedom for the test, and $\underline{d}/\underline{s}_{\underline{d}}$ is the standard error of the difference. This was the case for the breeding success data. For the survival data, an angular transformation was required before and after the above calculations to ensure homoscedasticity. In all cases, $\underline{d}$ was expressed relative to the mean of the control, and power was plotted against the original data scale (so that it equals 0.05 at the point where the scale equals the mean of the control).

We also evaluated the probability of the true difference $\underline{d}_t$ being greater or equal to a given magnitude, given the means actually observed for the radio-marked and control grouse. With homoscedasticity, this was given by $(1-\Phi((\underline{d}_t-\underline{d}_o)/\underline{s}_{\underline{d}})$ if $\underline{d}_t$ is expected to be positive, or by $\Phi((\underline{d}_t-\underline{d}_o)/\underline{s}_{\underline{d}})$ if $\underline{d}_t$ is expected to be negative, where $\underline{d}_o$ is the observed difference between the means. Data transformation and graphical presentation were as described for power.

Results

Radio-marked and wing-tagged grouse did not differ in any way other than the method of marking (Table 1). Analysis of body weight and wing length at time of autumn capture showed no difference between the two types of birds after removing the effect of age and sex (body weight: $F_{1,143} = 1.028$, $P = 0.312$; wing length: $F_{1,143} = 3.321$, $P = 0.070$).

The numbers of radio-marked and wing-tagged grouse recovered through recapture or found dead were compared to the number originally captured (Table 2). Recapture rates for all age/sex classes combined did not differ between radio-marked and wing-tagged grouse ($\chi^2 = 0.039$, df = 1, $P = 0.578$). The small sample sizes in each age/sex class precluded more detailed analysis, however the observed recapture rates did not differ markedly between the two groups in any age/sex class. Ten marked grouse were recovered dead, with seven (9.6%) recoveries of radio-marked birds versus three (3.8%) recoveries

Table 2. Numbers of marked red grouse subsequently recaptured (March 1994 and October 1994) or found dead (October 1993 to September 1994) near Langholm in southern Scotland.

Age	Sex	Type	Captured October 1993	Recaptured March 1994	Recaptured October 1994	All recaptures	Found dead
Adult	Male	Radio	24	5	2	7	2
	Male	Wing	25	4	1	5	2
	Female	Radio	16	1	0	1	3
	Female	Wing	13	2	0	2	0
Juvenile	Male	Radio	14	2	1	3	1
	Male	Wing	19	3	1	4	0
	Female	Radio	19	2	2	4	1
	Female	Wing	21	3	2	5	1
All		Radio	73	10	5	15	7
		Wing	78	12	4	16	3

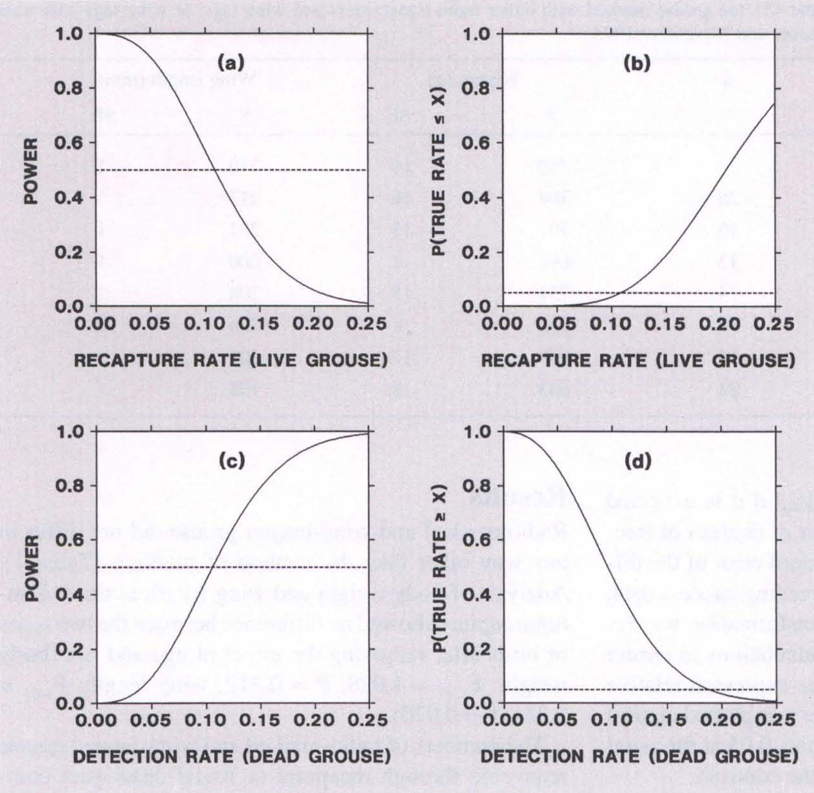

Figure 1. Power of the one-tailed test for differences in recovery rates of (a) recaptured and (c) dead radio-marked and control red grouse; and the probability (P) that the underlying "population" parameter for radio-marked grouse is at least as low as (recaptures in b) or as high as (kills in d) the x value given the means observed for radio-marked and control birds. In (b) and (d), the dotted lines indicate P = 0.05. (See Methods for detailed description).

of wing-tagged birds ($\chi^2 = 1.187$, df = 1, P = 0.138). Six radio-marked birds were killed by raptors and cause of death was not determined in one. Two wing-tagged birds were killed by raptors and one by a fox.

In a plot of power against the recapture rate of radio-marked grouse (Fig. 1a), the power of the test declines as the possible underlying recapture rate of radio-marked grouse increases to the observed recapture rate of wing-tagged grouse (20.5%). Thus, at the observed recapture rates of radio-marked grouse of 20.5% the power of the test is 0.05. The graphed probability that the "population" recapture rate of radio-marked grouse is as low as or lower than the observed value is given in Figure 1b. As the dotted line indicates P = 0.05, a recapture rate of 11% cannot be ruled out even though the observed recapture rates of radio-marked and wing-tagged grouse appear very similar. In the plot of power against the detection rate of dead radio-marked grouse (Fig. 1c), the observed detection rate is 9.6% for radio-marked grouse, and the power of the test is 0.4. The graphed probability that the "population" detection rate of dead radio-marked grouse is as high as or higher than the observed value is given in Figure 1d. As the dotted line indicates P = 0.05, a detection rate of 18% cannot be ruled out for radio-marked birds.

Clutch size and hatching success of radio-marked female grouse were compared to a control group of unmarked birds (Table 3). Analysis of clutch size showed no effects of marking after accounting for the effects of year and study area ($F_{1,79} = 0.028$, P = 0.566). Similarly, no effect of radio-marking was found on hatching success measured as the proportion of eggs hatched ($F_{1,79} = 0.734$, P = 0.804).

In the plot of power against the clutch size of radio-marked grouse (Fig. 2a), the power of the test declines as the possible underlying clutch size of radio-marked grouse increases to 7.8, the clutch size of control grouse. Thus, at the observed clutch size for radio-marked grouse

Table 3. Breeding success (clutch size and hatching success) of the 30 necklace radio-marked and the 61 control female red grouse in the two study areas (A and B) near Newtonmore in central Scotland, 1991-1994.

Study area	Clutch size						Hatching success					
	Radio-marked			Control			Radio-marked			Control		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
A	14	8.14	0.27	20	7.65	0.34	14	0.87	0.04	20	0.85	0.06
B	16	7.38	0.22	41	7.76	0.18	16	0.81	0.08	41	0.74	0.05

of 7.8 the power of the test is 0.05. The graphed probability that the true clutch size of radio-marked grouse is as low as or lower than the observed value is given in Figure 2b. As the dotted line indicates P = 0.05, a clutch size of 7.25 cannot be ruled out. In the plot of power against hatching success of radio-marked grouse (Fig. 2c), the power of the test declines as hatching success of radio-marked grouse increases to 0.78, the hatching success of control grouse. Thus, at the observed hatching success of radio-marked grouse of 0.84 the power of the test is less than 0.01. The graphed probability that the true hatching success of radio-marked grouse is as low as or lower than the observed value is given in Figure 2d. At P = 0.05, hatching success of 0.63 cannot be excluded.

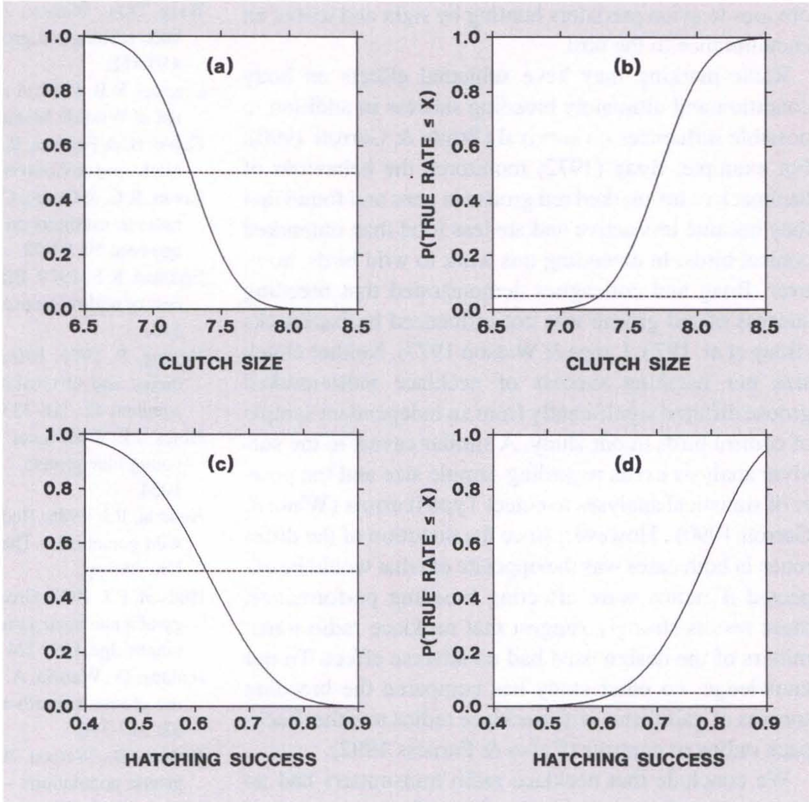

Figure 2. Power of the one-tailed test for differences in (a) clutch size and (c) hatching success of radio-marked and control red grouse ; and the probability (P) that the underlying "population" parameter (clutch size in b and hatching success in d) for radio-marked grouse is at least as low as the x value given the means observed for radio-marked and control birds. In (b) and (d) the dotted lines indicate P = 0.05. (See Methods for detailed description).

Discussion

We found that similar proportions of radio-marked and wing-tagged grouse were recovered as recaptures but that for birds recovered dead the proportion of radio-marked grouse was over twice as high as that of wing-tagged birds. As the difference was not statistically significant, the implication was that necklace radio transmitters of the design used did not make grouse more susceptible to predation in our study area. An important caveat attached to this conclusion was that statistically, it was impossible to prove that there is no effect of radio-marking, only that our experiment was unable to reject the null hypothesis of no effect (White & Garrott 1990). Although the current study is, to our knowledge, the most rigorous test yet conducted on the effects of necklace radio transmitters on the survival of wild galliforms and involved over 150 birds, the power analysis revealed that the chances of a Type II error were still high. Therefore, although we could not demonstrate statistically any effect of necklace radio transmitters on grouse survival, we cannot conclude, on the strength of our existing data, that no such effect exists.

Numerous studies have investigated the survival of galliforms fitted with backpack radio transmitters but, to our knowledge, only four others compared the survival of poncho or necklace radio-marked galliforms to untagged controls. Marks & Marks (1987) reported that Columbian sharp-tailed grouse with leg bands survived better than grouse with solar-powered radios on ponchos. They suggested that raptors selectively preyed on radio-marked birds, however, their poncho design produced a distinct audible effect from the antenna slapping against the wing which may have biased their results. In contrast, in studies on pheasants (Marcstrom et al. 1989) and black grouse (Willebrand 1988), recovery rates of birds with necklace radio transmitters were similar to those of control birds marked with bands. A recent study on rock ptarmigan demonstrated that breeding season survival rates of necklace radio-marked males were not significantly lower than those of unmarked controls (Cotter & Gratto 1995); questionably, these workers then pooled this data set with that from backpack radio-marked ptarmigan to argue for a negative effect of transmitters on survival. The necklaces used in these latter studies on grouse and pheasants were more compact than poncho designs and tended to be preened under the feathers, presumably making them less obvious to avian predators hunting by sight and less of an encumbrance to the bird.

Radio-marking may have sublethal effects on body condition and ultimately breeding success in addition to possible influences on survival (White & Garrott 1990). For example, Boag (1972) monitored the behaviour of backpack radio-marked red grouse in pens and found that they became less active and ate less food than unmarked control birds. In extending this work to wild birds, however, Boag and colleagues demonstrated that breeding success of red grouse was not influenced by backpacks (Boag et al. 1973, Lance & Watson 1977). Neither clutch size nor hatching success of necklace radio-marked grouse differed significantly from an independent sample of control birds in our study. A similar caveat to the survival analysis exists regarding sample size and the power of statistical analyses to detect Type II errors (White & Garrott 1990) . However, since the direction of the difference in both cases was the opposite of what would be expected if radios were affecting breeding performance, these results strongly suggest that necklace radio transmitters of the design used had no adverse effect. To our knowledge, no other study has compared the breeding success of galliforms with necklace radios to either backpack radios or controls (Calvo & Furness 1992).

We conclude that necklace radio transmitters had no measurable effect on survival and breeding success of red grouse in our study areas. We concur with Marcstrom et al. (1989) that necklace radio transmitters are preferable to backpacks for grouse and pheasants and possibly other galliforms, provided that they are well-fitted, inconspicuous, and below a threshold weight of 3% of body mass.

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