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THE USE OF RADIO TELEMETRY TO MEASURE THE FEEDING BEHAVIOR OF BREEDING EUROPEAN GOLDEN-PLOVERS

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Abstract.—There have been few quantitative studies of avian feeding behavior using radio telemetry. This study describes a new method for measuring feeding behavior of European Golden-Plovers (*Pluvialis apricaria*) by counting the number of changes in pulse pattern given off by position-sensitive transmitters. This method proved more accurate than counting the total number of pulses and in addition is not likely to be affected by individual transmitter variation or temperature. Feeding rates and overall behavior of birds were not affected by transmitters.

LA UTILIZACIÓN DE RADIOTELEMETRÍA PARA MEDIR LA CONDUCTA ALIMENTARIA DE INDIVIDUOS DE *PLUVIALIS APRICARIA*

Sinopsis.—Hay pocos estudios cuantitativos de los hábitos alimentarios de aves utilizando radiotelemetría. En este trabajo se describe un nuevo método para medir la conducta alimentaria de individuos de *Pluvialis apricaria.* Este consiste en contar el número de cambios en patrones de pulso registrados por un transmisor sensitivo de posiciones. Este método es más preciso que el contar el número total de pulsos y además no suele ser afectado por la temperatura o variaciones individuales del transmisor. La tasa de alimentación y la conducta en general de las aves no fue afectada por el radiotransmisor.

The use of radio telemetry on birds is often restricted to qualitative activity data, with relatively few studies attempting detailed quantitative measurements of behavior. Kenward (1982) used position-sensitive transmitters to record different activities of Goshawks (*Accipiter gentilis*). Exo (1993) and Exo and Scheiffarth (unpubl. data) described a constant monitoring system coupled with mercury-tilt switch transmitters that could differentiate between foraging and non-foraging. Stock et al. (1992) estimated the proportion of time spent feeding by Brant (*Branta bernicla*) by measuring the amount of time that slow or fast pulses were given off by position-sensitive transmitters. To date, this is the most accurate technique for measuring feeding activity. Given the success of Stock et al. (1992) the method seemed applicable to Golden-Plovers, which feed in a much more systematic way than geese (i.e., bending down and then alert in regular fashion). Therefore, the objective of this study was to measure feeding rate of European Golden-Plovers using radio telemetry and to test the effects of tags on the birds behavior.

MATERIALS AND METHODS

Study area.—The study was carried out on two moorland areas in the northern Pennines, County Durham, UK from April–July 1994: Widdybank Fell, part of Teesdale National Nature Reserve (54°40′N, 2°16′W) and Chapel Fell (54°43′N, 2°12′W), and the two areas of upland farmland adjacent to these moors in Teesdale and Weardale, respectively.

Transmitters.—Adult European Golden-Plovers were trapped on the nest using a heart-shaped walk-in trap and 3.96 g (PD-2) mercury-tilt switch radio transmitters (supplied by Holohil Systems, Canada) were attached. In all, 13 transmitters were attached to color-banded individuals (only one individual from any nesting pair was tagged), on the back between the carpal joints either by direct gluing to the base of the feathers and back or by first gluing the radio to a 0.75-cm^2 piece of gauze and then attaching to the base of the feathers and back (Kalas et al. 1989, Kenward 1987). The former technique was used for two transmitters initially but they fell off after a few days and so the latter technique was used for the remaining 11 transmitters. The lightest individual to which a transmitter was attached weighed 197g (mean = 209.5g ± 3.54 SE), so the transmitter was at most equivalent to 2.01% of the body mass. The transmitters were 21 × 12 × 6 mm with a 215-mm whip antenna. Transmitters were attached so that when the bird was standing the pulse rate was approximately half (34.8–37.2 pulses per min) that recorded when the bird was in a feeding (head down) position (67.8–76.2 pulses per min) (Fig. 1). Each transmitter was set at a constant pulse rate, but the exact rate differed between individual transmitters. The fate of all transmitters was monitored daily and detached radios were recovered after a maximum of 2 ds (i.e., the location remained constant for a day).

Transmitters could be detected up to 2 km away over hilly ground. The pulse rate of the tags varied with temperature, from approximately 30 pulses per min at 0 C to approximately 50 pulses per min at 40 C (Holohil Systems, 1992). Temperature readings were taken at a weather station at Widdybank from April to June. Temperatures varied from a daily minimum of −3.0 to 21.9 C (a difference of approximately ten pulses per min). However, temperature did not significantly affect the control data as all readings were taken during the day in May (temperature not varying greater than 4 C).

Measurement of feeding behavior.—As part of another study on habitat selection, radio-tagged European Golden-Plovers were located once during the day and once at night, for a minimum of 3 d/wk, to measure activities including feeding rate. Feeding behavior could be distinguished from other activities (such as roosting and incubating) by the regular pattern of pulses emitted as the bird bent over and back up again. The data were assigned to feeding only when this pattern occurred consistently over a time period of less than 20 S (i.e., slow, followed by fast and then slow pulse rate, Fig 1). If the slow-fast-slow pulse pattern were recorded over a period of over 20 seconds (98% of pecks observed in fields were less than 20 seconds, n = 420) then data were not recorded as feeding. For radio-tagged and control birds (i.e., non-tagged individuals observed in fields during daylight, see below) a peck was defined by each occasion the head bent down and tilted the back so it was parallel with the ground or beyond (Fig. 1).

Feeding behavior was quantified as the rate of pecking. Two measurements were taken each time an individual was located: (1) the total num-

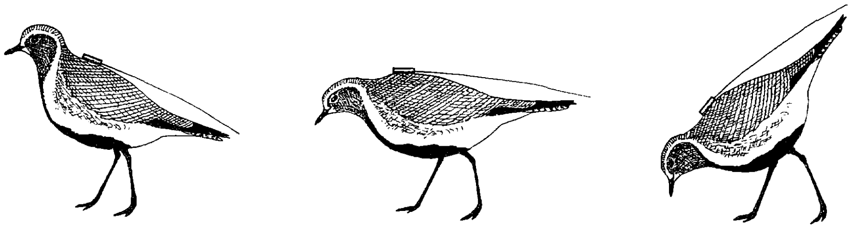

FIGURE 1. Feeding Golden-Plovers with radio transmitters. A peck was recorded for both radio-tagged and control birds in the right two (faster pulse rate) but not in the left one (slower pulse rate).

ber of pulses per 1-min sample, and (2) an estimate of the number of pecks by the relative change in the pattern of pulses (the pulse-pattern method) per 1-min sample. For example, a slow pulse pattern followed by two pulses at the fast rate followed by a slow pulse was recorded as one peck. If that slow pulse was followed by another two fast pulses that was recorded as a second peck. A minimum of two pulses at the fast pulse rate were necessary to record one peck.

To validate the two techniques, data were taken from five tagged females feeding in fields during the day from 1000–1300 h (using a car as a blind). One observer recorded the actual number of pecks made in 1-min focal samples, and another independent observer simultaneously recorded an estimate of the number of pecks using the two measurements described above. A minimum of five samples was taken from each female. It was only possible to observe tagged females (off-duty from incubation) during the day as males were incubating during this time and both parents guarded chicks during the daytime (Parr 1980; Whittingham, unpubl. data).

Effect of transmitter on peck rate and activity.—All comparisons of tagged and control birds refer to females only. Three types of data were collected to test potential effects of radio transmitters: (1) direct observations of the peck rate of radio-tagged birds were compared with peck rates from randomly selected untagged females in fields, (2) peck rate was compared with the length of time the transmitter remained attached, and (3) during 1-min focal samples time spent preening, roosting, feeding, and alert was recorded from five tagged females and from seven untagged females feeding at the same time as the tagged birds (again using a car as a hide). For ease of sampling, each 1-min sample was broken down into six 10-s blocks. The predominant activity (i.e., >50%) in any one block was assigned to that sample. If no one activity accounted for more than 50% of the 1-min sample, then it was discounted (less than 6% of records, n = 300). The overall number of records within each category were summed and a contingency table constructed to test for differences between tagged and controls within all four categories. In addition, to test for within category differences observations were pooled from each bird and

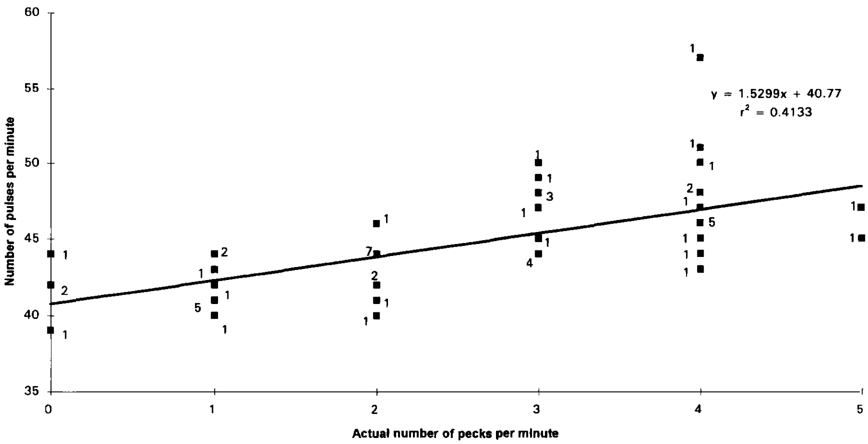

FIGURE 2. Estimating feeding rate of European Golden-Plovers from total number of pulses emitted by radio transmitter. The number of data points are shown next to each square.

the proportion of time spent in each category compared between tagged and control birds using Mann-Whitney *U*-tests.

RESULTS

The fate of transmitters.—The 13 transmitters either became detached (8) or the bird disappeared (5) as follows: four after 2–10 d, four after 15–20 d, one after 20–25 d, three after 30–35 d, and one after 48 d. Radios stayed attached for a mean of 19.5 d (±3.73 SE). However, this is likely to underestimate attachment time because when a radio could not be located due to the individual disappearing, the last known time of observation was used. Although 45% of radios disappeared, these were on birds that deserted the nest or disappeared from the breeding moor and valley. The radios that disappeared may have been attached to individuals who left the area either after successful breeding or nest desertion (only one individual deserted the nest immediately after the tag was fitted, other birds that deserted the nest did so at least 10 d after the tag was attached). There were no known radio failures.

Estimating peck rate by radio telemetry.—The results of the two methods of estimating feeding rate are presented in Fig. 2 and 3. The total number of pulses emitted by transmitters correlated with the number of pecks/min (r^2 = 0.413, df = 53, $P < 0.001$; Fig 2). The results for the pulse-pattern method provided a better fit to the data (r^2 = 0.748, df = 53, $P < 0.001$; Fig. 3).

By plotting the equation of the best-fit line derived from the pulse-pattern method with the perfect predictor line (i.e., a 45% slope on which every peck is perfectly recorded by the pulse pattern method), it is possible to examine the relationship between estimated peck rate and the actual peck rate (Fig. 3). Ninety-five% confidence limits around the re-

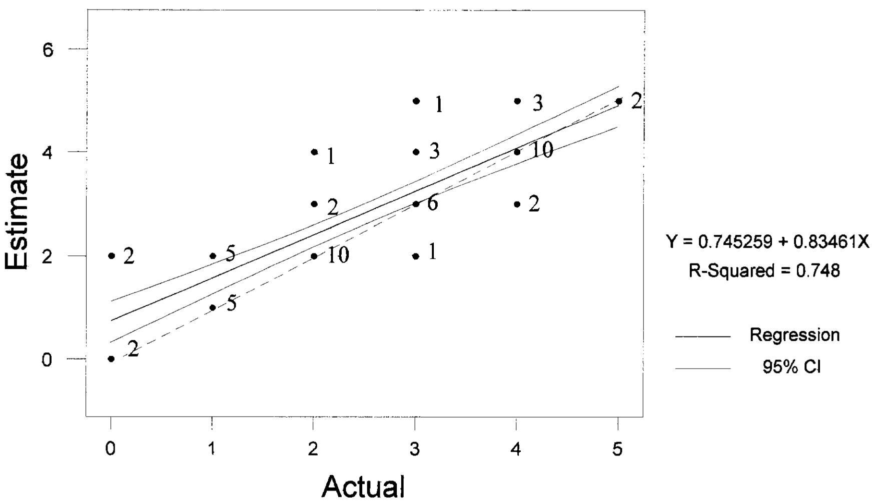

FIGURE 3. Estimating feeding rate from change in pulse pattern. The dashed line represents the theoretical perfect fit line. The number of data points are shown next to each circle. Ninety-five% confidence intervals are presented around the regression line. Estimated no. of pecks = 0.745 + 0.835 (actual no. of pecks).

gression line indicated that the pulse-pattern method significantly overestimated number of pecks recorded up to approximately three pecks, beyond which peck rate was accurately predicted. If the two lines were extended then this would indicate higher peck rates were underestimated by the pulse pattern method, but the precise nature of the relationship when peck rate is higher cannot be determined.

The effect of transmitters on behavior.—Peck rate, measured from direct observation, did not differ significantly between tagged birds ($\bar{x}$ = 2.53 ± 1.84 SE) and controls ($\bar{x}$ = 2.90 ± 1.81 SE) (t = 1.43, df = 104, $P >$ 0.05). In addition, no relationship was found between the length of the time that the transmitter was attached and peck rates of radio-tagged birds (r^2 = 0.004, df = 129, $P >$ 0.05).

Activity budgets of radio-tagged females observed during the day were compared with those of control females, observed in study fields in Teesdale and Weardale. There was no overall difference between all activities of tagged and control birds (χ^2 = 6.37, df = 3, $P >$ 0.05; Table 1). No difference was found between any of the activities except roosting (Mann-Whitney U-tests, $P >$ 0.05). Control females spent more time roosting than radio-tagged females (Table 1).

DISCUSSION

Fate of radios.—The length of attachment was similar to that found by Kalas et al. (1989), but does not compare favourably with attachment times of harnesses on similar species (e.g., Wood 1986) or with some tail mounts on other waterfowl (Giroux et al. 1990). Harnesses were not used

TABLE 1. Mean proportion time spent (±1 SE) in four activities of radio-tagged (n = 5) and untagged (n = 7) adult female European Golden-Plovers. Only the frequency of roosting differed between groups ($P < 0.05$, Mann-Whitney U-test).

Activity	Tagged	Untagged
Feeding	0.763 ± 0.135	0.658 ± 0.067
Roosting	0.023 ± 0.017	0.092 ± 0.015
Preening	0.175 ± 0.119	0.197 ± 0.058
Alert	0.038 ± 0.024	0.053 ± 0.018

in this study because they could have been present for the rest of an individual's life and might have snagged (Kenward 1987), and they would also have increased the overall weight attached to the bird. Therefore, glue-on transmitters are recommended for use on Golden-Plovers.

Measuring feeding behavior.—The pulse-pattern method has two advantages over counting total number of pulses. Neither temperature change nor individual variation in transmitter pulse rate is likely to affect the pattern of *relative* frequencies. Both of the latter may explain the increased accuracy of the pulse-pattern method over counting the total number of pulses.

The pulse-pattern method overestimated pecks at low peck rates. The overestimation of actual pecks in the field could be explained by error when recording. While observing the ground for potential prey, a bird may bend enough to tilt the transmitter and record a peck (i.e., false pecks), but a peck might not be assigned by the observer. There are a few records using the pulse pattern which underestimate the number of actual pecks (though the 95% confidence limits around the regression line do not lie below the theoretical perfect fit line; Fig. 3). Underestimation may be due to the increased probability of not recording pecks when peck rate is high during the focal period, the number of pecks during the focal period being related to the time of each peck (pecks being shorter when peck rate per min is high).

The accuracy of the method would be improved by decreasing the time interval between pulses, especially if this method were used for a species with a faster foraging rate. This would increase the probability of recording fast pecks. Another improvement that could be used in conjunction with the latter would be to alter the angle of the mercury-tilt switch so that the bird would have to bend over farther to record a peck (decreasing the number of false pecks) and increasing the number of short pecks recorded.

There is scope for further work on detecting successful and unsuccessful pecks from the pattern of pulses emitted, which coupled with a constant monitoring device would enable the energetic requirements of breeding Golden-Plovers to be accurately measured.

Effects of transmitters.—Kenward (1987) thought that, at the least, short-term effects (such as reduced foraging or increased preening/grooming) would be present after most tagging. Despite this, most studies of radio tracking assume that transmitters do not impair animals (Giroux et al. 1990), though some have demonstrated detrimental effects (e.g., Greenwood and Sargeant 1973, Nenno and Healey 1979, Pietz et al. 1993).

This study showed no overall difference between control and tagged birds in the four activities measured (feeding, preening, alert, or roosting). However, control birds spent more time roosting than tagged birds. This may be because some controls were not off-duty breeding birds and therefore behaved differently from the radio-tagged breeders. Non-breeders may have more time to engage in energetically less important activities, such as roosting, than incubating females who need to maximize energy intake when off-duty. However, both failed and successful breeders tend to leave the area within a few days and nearly all birds that were going to breed had begun nesting when observations of feeding rates were made. The number of controls which were non-breeders was likely to have been small. This is indicated by the lack of any overall difference when all four activities were analyzed together.

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