J. Field Ornithol., 60(3):315-322

TELEMETRIC EGG FOR USE IN EGG-TURNING STUDIES

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Abstract.—Observational methods used in the study of egg-turning behavior in birds require removing the bird from the nest while egg positions are determined. Such disturbances may alter behavior. We developed a telemetric device that transmits egg position. The device is small, inexpensive, easily constructed, and continually transmits egg position with a minimum accuracy of ±22.5°.

APARATO TELEMÉTRICO PARA ESTUDIAR EL MOVIMIENTO DE HUEVOS DURANTE LA INCUBACIÓN

Resumen.—Para estudiar el movimiento de huevos durante la incubación, se requiere el levantar el ave del nido para observar la posición de los huevos. Esta perturbación puede afectar el comportamiento del pájaro. Desarrollamos un aparato telemétrico pequeño, de bajo costo y fácil de construir, que continuamente transmite la posición del huevo con una presición de ±22.5°.

Researchers studying egg-turning behavior in incubating birds commonly mark the eggs in some way and observe their positions through time (Caldwell and Cormwell 1975, Stewart 1971). However, results may be inaccurate because some species turn eggs so that any mark is hidden (Holcomb 1969), not all egg-turnings can be detected, and disturbances during observation may alter natural turning rates.

A telemetric egg that transmits position would eliminate these difficulties. Varney and Ellis (1974) suggested the use of an array of photoresistors inside a telemetric egg. Photoresistors would require artificial lighting for recording positions at night, which may alter the rate the female turns her eggs, and also may report inaccurate positions if shaded by another egg or if the bird is on the nest. The objective of this project was to design and test a telemetric device that would continually transmit the position of an egg under natural conditions.

METHODS

Egg design and construction.—The design of the egg circuitry was adapted from Mackay (1970, p. 10). A circular mercury sensor/switch was used to determine position (Fig. 1). The carbon-coated portions of the contact rings from two potentiometers (Archer Cat. No. 271-229)

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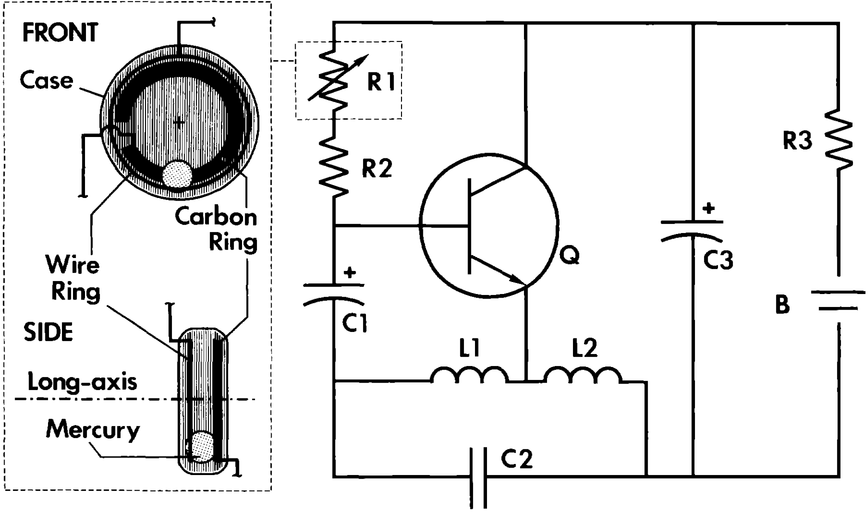

FIGURE 1. Schematic diagram of the egg circuitry. Parts list. Resistors: R1—1 megohm potentiometers [2] (Archer Cat. No. 271-229); R2—330,000 ohms ⅛-watt, 5%; R3—1000 ohms ⅛-watt, 5%. Capacitors: C1—1 uf, 35 volts, tantalum; C2—0.001 uf, 500 volts, ceramic; C3—4.7 uf, 35 volts, electrolytic. Other components: B—1.5 volt mercury-celled watch battery; L—antenna coil 3.0 cm diam., 40 ga. wire; L1—12 turns; L2—24 turns; Q—2N2222, NPN small-signal transistor. Miscellaneous: Mercury (<1 g), electronic component breadboard, conductive epoxy, standard epoxy, stainless steel wire, hook-up wire, solder.

were trimmed and joined to make an almost-complete circle, leaving a gap of approximately 2 mm. Conductive epoxy (used to repair automobile rear window defrosters) was used to join the carbon ring halves. The ring was then mounted into one of the original potentiometer cases with standard epoxy, assuring the epoxy filled any openings in the case, and didn't contact the exposed conductive side of the ring. A circular stainless steel wire was mounted in the other plastic case and epoxyed in place, again using the epoxy to fill holes in the potentiometer case and assuring that throughout its length the wire was not completely covered. A hole was drilled in the side of each case a minimum distance above the mounted component. Stainless steel 22 ga. wires were passed through each hole and joined to the components with conductive epoxy. The wires were joined to one end of the carbon ring, and to any position on the circular wire. The hole drilled in each case for the wire was sealed with standard epoxy. The wires were trimmed to approximately 3 mm. The edges of the cases were sanded to assure a tight fit, a drop of mercury (<1 g) was placed in one case, and the two cases were taped together. A multimeter was used to check response of the sensor. Mercury was added or removed until the sensor made contact throughout its range, yet contact was broken if more than approximately 40° off horizontal. The cases were joined with standard epoxy.

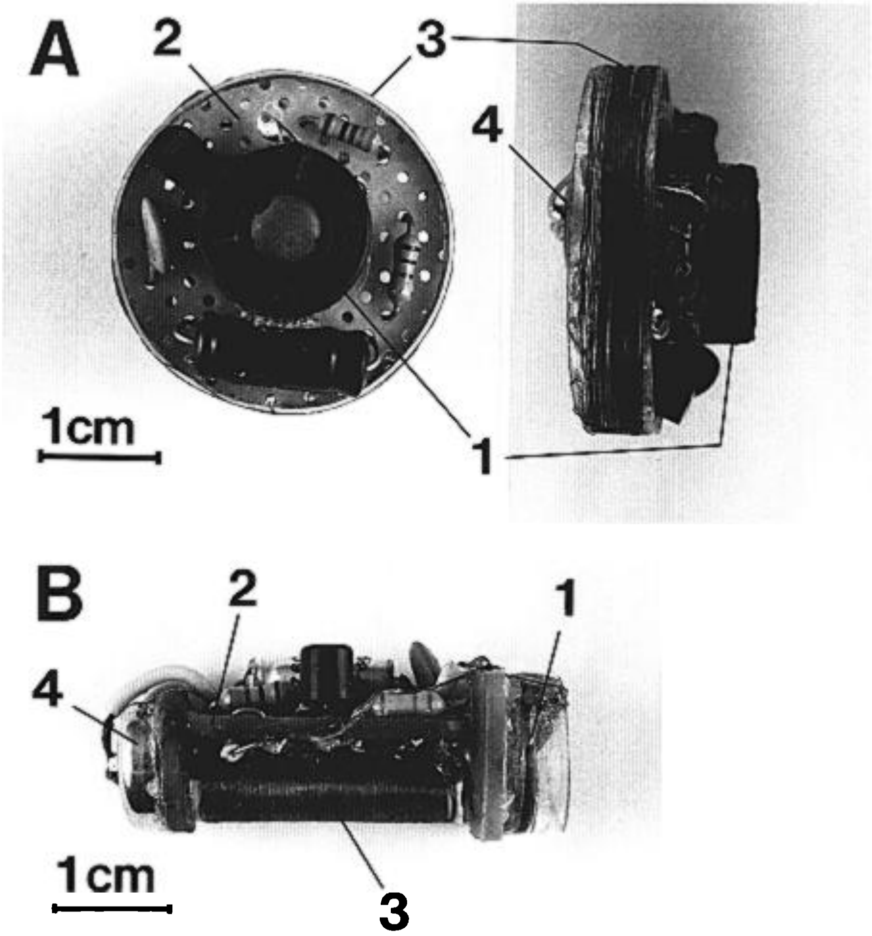

FIGURE 2. A: The telemetric device used in the test. B: Another style, with modifications made to the antenna coil (wrapped around a soda-straw; L1—50 turns, L2—100 turns). In both photographs: 1—Position Sensor, 2—Component board, 3—Antenna coil, 4—Battery (partially hidden in Fig. 2A).

Figure 1 contains a schematic diagram of the egg circuitry. A circle 2.8 cm in diameter was cut from pre-drilled electronic component board. A 0.5 cm wide strip of plastic, such as from 2 liter beverage containers, was cemented around the circumference of the board (Fig. 2). The antenna coil was wound around this band. Components were installed on one side of the board, connections made on the other. We soldered connections to the battery, which requires care to prevent overheating. A battery holder may be used. The device tested weighed 15.2 g. The components cost $6.55.

The device was tested with a domestic chicken; a standard grade AA egg shell was used to house the device. The egg was sawed in half along its long-axis, the shell was lined with dental acrylic (Varney and Ellis 1974), and further strengthened with wall spackle. The device and shell were weighed and weight (coinage) was added to equal the average of eggs used in testing, 62 g. Balance was approximated, though not critical; eggs commonly balance asymmetrically (Romanoff and Romanoff 1949). The device was mounted in one half of the shell, the two halves joined with a small amount of spackle, and the joint painted with acrylics to appear natural.

Receiving and recording equipment.—The receiver of the transmitted signal was a small AM 'pocket radio' with an earphone jack. An antenna was made by wrapping 18 loops of 22 ga. wire around the base of the nest box. The loop-antenna leads were wrapped around the radio antenna. The signal received from the transmitter by the radio was sent to a decoder (see Appendix), a device mounted on the User Port of a Commodore 64 Personal Computer. The decoder counted the number of peaks in the signal, during a time period which is adjustable, converting rate of pulsing into a number between 15 and 256. This number was converted into an 8-bit binary number, then sent to the computer. The decoder components cost less than $10.00. A continually executing Basic program (see Appendix) detected changes in position and recorded the data on disk.

Stewart (1971) showed that eggs may be moved and supported so that their long-axis is vertical (the great end or small end pointing up). The circular position sensor would not respond accurately in this position, thus the sensor is designed to disconnect the circuit. If the long-axis is more than approximately 40° off horizontal, the mercury falls away from one side of the sensor and breaks the circuit. The receiving equipment then records a zero. Placing the egg on end is also used to turn the device off for storage.

To test the device four natural eggs and the telemetric egg were marked to indicate position during observation, then were incubated by a domestic chicken for 22 d. Transmitted pulsing rate, which is directly related to position (Fig. 3), was stored every hour and every time a change in position occurred. For comparison, the position of the eggs was observed and recorded hourly for eight 8-h periods. Positions were estimated to the nearest 45°.

RESULTS

The average turning rate for all eggs for the hours observed was 62.4°/h. This rate was similar to the 61.2°/h observed in mallards (*Anas platyrhynchos*) by Caldwell and Cormwell (1975). A Bonferonni 95% confidence interval test (Neter et al. 1983) showed no significant difference in turning rates for the telemetric egg and natural eggs. A paired Student's t-test (Snedecor and Cochran 1980) used to compare the recorded data with the observed positions showed no significant difference ($t = 0.79$, 71 df, $P > 0.05$), thus the telemetric egg circuitry tested accurate to at least ± 22.5°. The average turning rate calculated from telemetric data for eight

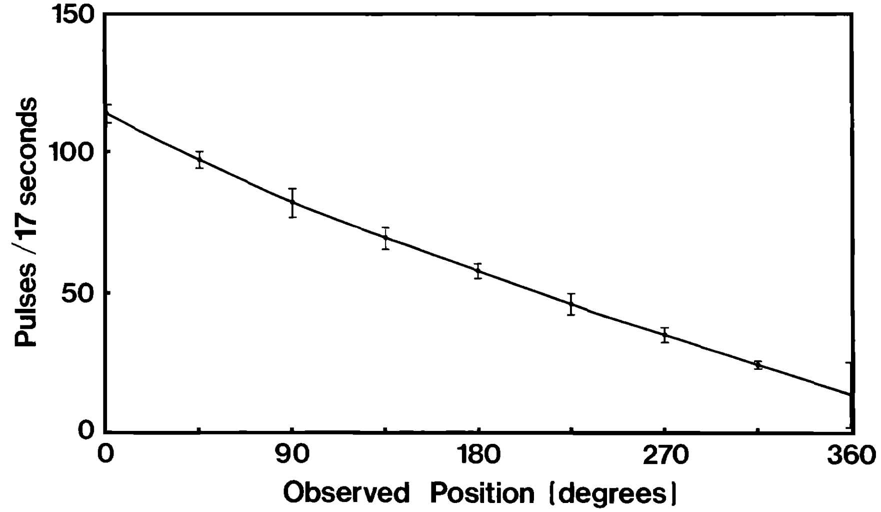

FIGURE 3. Pulses per time interval plotted against observed position. The shape of the line is not critical, only that a near one-to-one relationship between the axes exists. Standard error bars are shown.

8-h periods not observed was 67.0°/h. Comparing this with 62.4°/h for hours observed suggests that observations alter turning behavior.

DISCUSSION

After removing the hen from the nest to check the position of the eggs, we observed that she would move the eggs while shifting and settling upon the nest. Thus hourly disturbances apparently influenced natural turning rates. Several modifications have been made since the test of the prototype design. The circuitry with coil and battery is now approximately 3.0 cm in diameter and 2.0 cm thick. Units have also been built which are long (3.8 cm) and thin (1.6 cm). For comparison, the egg of the ruffed grouse (*Bonasa umbellus*) is approximately 3.9 × 2.9 cm (Romanoff and Romanoff 1949).

We found that the telemetric device transmits at a slower rate at incubation temperature than at room temperature, due to transistor characteristics changing with temperature. Because the hen was on the nest almost continually, this difference did not affect test data. With birds that are off the nest for longer periods, this difference may affect accuracy. Including a circuit with constant resistance for reference will allow comparisons to be made and any drift to be recorded. This would require a switching circuit inside the egg, increasing its complexity. Another method would be to include a second transmitter that transmits temperature on another frequency. This transmitter could be in the same or a different egg. Filling excess space within the transmitter shell with paraffin will help to retain heat (Varney and Ellis 1974). Finally, the transmitter should be calibrated at incubation temperature.

As designed the system feeds into a computer, but this was for convenience only. In field work a strip-chart recorder could be used to record data (see Varney and Ellis 1974). The antenna would wrap around the base of the nest.

The system was designed to detect turning, but the position sensor merely alters resistance. Any electrical sensor that varies resistance could be used. For example, a thermistor, which measures temperature, or a photoresistor, which responds to light levels, could be installed (Mackay 1970).

The system described recorded position changes continually for 22 d. The circuitry can be constructed by someone with little electronic experience, is inexpensive, and has a battery life of 1.5–7 yr, dependent upon average pulse rate. We believe the desribed method of egg turning study is superior to observational methods used in the past.

ACKNOWLEDGMENTS

We wish to thank Dr. John Crawford for his support and assistance with the preparation of this manuscript. Also thanks to Kevin Nichols, alumnus of Mechanical Engineering, Oregon State University, for his initial designs and encouragement. The comments and suggestions of referees is appreciated. Our thanks are also due to many others too numerous to mention. This project was a team effort.

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Received 13 Jan. 1988; accepted 25 Feb. 1989.

APPENDIX

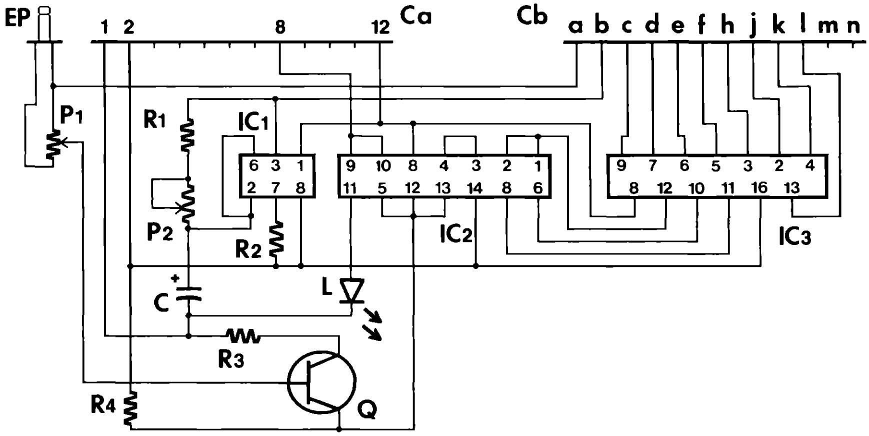

FIGURE I. Schematic diagram of decoder used to count clicking rate of the telemetric egg. Designed for use in the User Port of the Commodore 64 computer. Port pin description allows translation into other formats. Parts list. Resistors—All are ⅛-watt, 5% unless otherwise noted: R1—100,000 ohms; R2—10,000 ohms; R3—1000 ohms; R4—100 ohms; P1—500 ohms potentiometer; P2—100,000 ohms potentiometer. Semiconductors: IC1—7555 timer; IC2—7400 quad nand gate; IC3—4040 12 stage binary ripple counter; Q—2N5449 transistor; L—light-emitting diode. Other components: C—100 uf, 25 volt capacitor; Ca, Cb—female 24 pin connector; EP—ear phone jack. Miscellaneous: Electronic component breadboard, wire, solder. Port pin descriptions: Ca—1, 12—ground; 2—+5 volt; 8—handshaking line. Cb—a—ground; b—handshaking flag; c, d, e, f, h, j, k, l—output bits 0 to 7, respectively.

```
100 DIM ps%(100), tm$(100), dy%(100), an%(4,2)
110 INPUT "Time"; ti$                                  REM Example 130000 is 1:00
                                                           pm
120 INPUT "Day of test"; da%
130 i% = 0: j% = 0
140 fl% = 1                                            REM Time flag used in saving
                                                           data
150 OPEN 8,8,8, "@:datafile, s, w"
160 IF (MID$ti$, 3, 2) = "00") AND (fl% = 1) THEN      REM Store arrays on disk
        GOSUB 1000                                         hourly
170 IF (MID$(ti$, 3, 2) = "30") THEN fl% = 1           REM Reset flag
180 GET a$: IF a$ = "Q" THEN GOSUB 1000: CLOSE         REM Allow for break of pro-
        8: END                                             gram
190 IF PEEK(56589) = 0 THEN GOTO 160                   REM Loop if no new data
200 dt% = PEEK(56577): PRINT "Cls" dt% i% ti%          REM Get data; echo to screen
210 IF i = 0 THEN GOSUB 2000: GOTO 500
220 FOR z = 0 TO 4: an%(z, 2) = 0: NEXT z
230 FOR x = 0 TO 4
240 IF (dt% < an%(x, 0)) OR ( dt% > an%(x, 1)) THEN    REM Check current data
        an%(x, 2) = 1                                      against past; if different,
250 PRINT an%(x, 0) an%(x, 1) an%(x, 2) j%                 set Data flag
260 NEXT x
270 FOR z = 0 TO 4: IF an%(z, 2) = 1 THEN GOTO 500:    REM If Data flag set, save cur-
        NEXT z                                             rent data in arrays
280 IF dt% > (ps%(i% - 1) - 10) and dt% < (ps%(i% - 1) REM Save current as turn only
        + 10) THEN GOTO 500                                if change is > 10 clicks
290 GOSUB 2000: GOTO 500
500 an%(j%, 0) = dt% - 10: an%(i%, 1) = dt% + 10
510 j% = j% + 1
520 IF j% = 5 THEN j% = 0                              REM Save 4 most current posi-
530 GOTO 160                                               tions in arrays
1000 IF LEFT$(ti$, 2) = "00" THEN da% = da% + 1
1010 FOR q = 0 TO i%
1020 PRINT #8, ps%(q)                                  REM Save to disk memory
1030 PRINT #8, tm$(q)
1040 PRINT #8, dy%(q)
1050 NEXT q
1060 i% = 0: fl% = 0
1070 RETURN
2000 ps%(i%) = dt%: tm%(i%) = ti$: dy%(i%) = da%       REM Save position, time, and
2010 i% = i% + 1                                           day in arrays
2020 RETURN
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FIGURE II. Program, written in Commodore Basic, used to detect changes in position of transmitting egg. REM (remark) statements are included to assist in translation into other languages, if necessary.