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A MULTIPLE SENSOR SYSTEM FOR MONITORING AVIAN NESTING BEHAVIOR

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Avian nest construction, laying and incubation time budgets often provide a temporal framework for ethological, physiological and ecological investigations. Numerous methods have been devised to measure nest attentive and inattentive periods. Early approaches, reviewed by Kendeigh (1952:5) and Skutch (1962), involved observations from a blind or simple mechanical switch devices connected to graphic recorders. Advances in electronic and photographic equipment have led to the development of many useful instruments for detecting the presence of birds at or near nests. Thermistors and thermocouples have been positioned in nests (Baldwin and Kendeigh 1927, Farner 1958, Norton 1972), in eggs (Huggins 1941, Snelling 1972, Caldwell and Cornwell 1975 and others), or in artificial eggs (Holstein 1942, Kossack 1947, Norton 1972). Photoelectric sensors were placed in or near nests by Kessler (1962) and Weeden (1966), while time lapse cameras were used by Weller and Derksen (1972) and Caldwell and Cornwell (1975). Gilmer et al. (1971), Varney and Ellis (1974) and Miller (1976) have described telemetry systems. Pulliainen (1978) recently employed closed-circuit television to record nesting behavior.

Each approach reflected the limitations imposed by the species studied, the availability and cost of electronic and photographic equipment and the inventiveness of the investigator(s). Skutch (1962) emphasized, and we believe correctly, that automatic monitors cannot substitute for observation. Yet, investigations of individual variation or nocturnally active birds cannot easily be done by observation alone. Nocturnal observations require expensive night-vision equipment, and large samples are necessary for statistical analysis of differences among individual birds. Varney and Ellis (1974) criticized thermistor and thermocouple techniques because a wire must be attached to an egg; they recommended a telemetry system in an artificial egg. However, artificial egg temperatures differ from heat levels in developing eggs (Drent 1970). Earlier methods used a single sensor, not allowing crosschecking for accuracy or simultaneous monitoring of egg temperatures, incubating bird behavior or identity.

This paper describes the construction and field application of a multiple sensor (photoelectric-thermistor-photographic) system for nesting studies. While employed primarily in waterfowl investigations to date, the apparatus has potential for studies of a wide range of species.

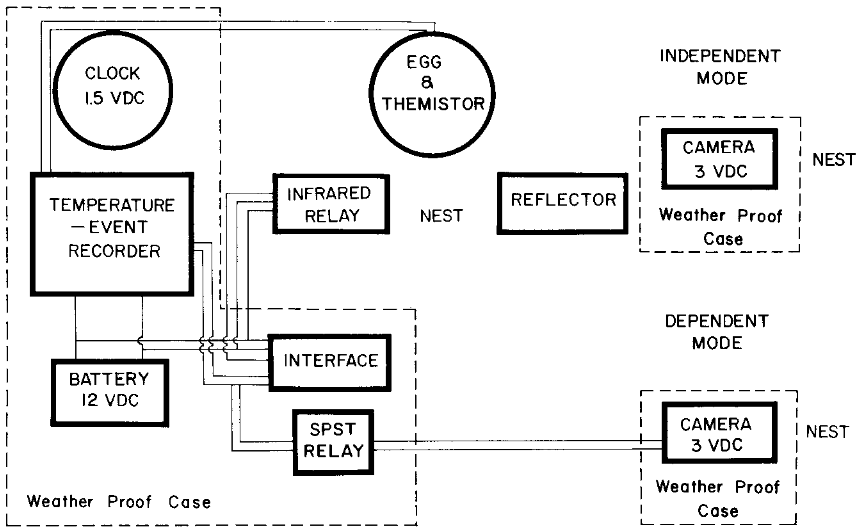

FIG. 1. Block diagram of the multiple sensor system.

METHODS AND MATERIALS

Instrument design and construction.—Basic instrument components are: an infrared photoelectric relay (Microswitch MLS-3A), a medical thermistor (Rustrak 1331), a super-8 movie camera (Minolta XL-401), a strip-chart, temperature-event recorder (Rustrak 2133), an infrared relay interface and a 1.5 VDC clock (Fig. 1). The recorder, interface and clock are housed in a weather-proof case. The infrared relay and camera are positioned near or at the nest and connected to the recorder and interface, and the thermistor probe is inserted in an egg or in the nest. Connections are via multi-conductor, insulated cable. The recorder, thermistor and relay are powered by one or two 12 VDC batteries; the clock and camera are driven by rechargeable 1.5 VDC dry cells.

Detectors may be operated independently or in concert. The presence of a bird at the nest is detected when the infrared beam is blocked by the bird's body. Interruption of the 5-mm diameter beam, projected from the lens of the relay to an 8-cm plastic reflector and back to the relay, closes the circuit between the relay and the interface, which, in turn, closes the circuit to the event channel of the recorder (Fig. 1). The interface (Fig. 2) is necessary because the infrared relay switching transistor has a maximum current limit of 120 mA and the minimum current needed to activate the event pen is 500 mA. When inserted in the egg air cell or nest, the thermistor monitors the bird's presence by recording cooling during an

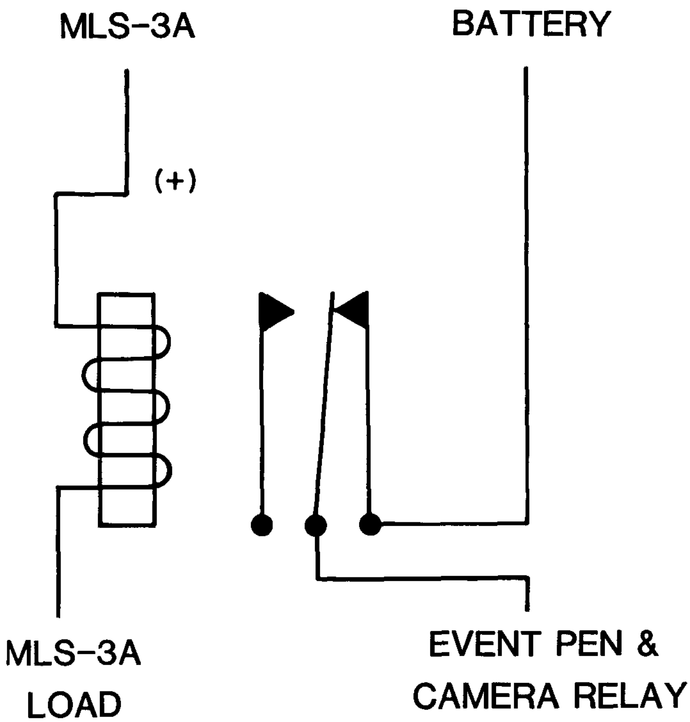

FIG. 2. Schematic diagram of infrared relay-recorder interface.

absence. In independent mode, the camera shutter is activated by an internal timer at preselected intervals over a range of 1–60 sec, recording on film the nest and its surroundings during daylight and by using a strobe-light at night. In dependent mode, single frame exposures are triggered by interruption of the infrared beam so that the animal blocking the beam is photographed.

An independent time reference is needed for the recorder because the chart speed varies with the battery voltage, which is a function of power demand, battery condition and temperature. This is attained by opening briefly the thermistor circuit once an hour. A magnetic reed switch attached to the noon position of the clock with a small magnet glued to the minute hand provides an inexpensive but accurate reference.

Humid conditions may cause chart paper jamming. This can be prevented by encasing the recorder in an airtight case containing a noncorrosive desiccant ($CaSO_4$).

Field application.—The 12 VDC power supply permits monitoring in remote locations and the cable connections allow maintenance of the recorder without disturbing the bird at the nest. Installation timing and configuration depend on the characteristics of the species being studied. A typical application entails locating a nest, preferably during the prelaying or early laying stages, and choosing or constructing a suitable site for the instrument case; placement of the relay, thermistor probe, camera or combination of these at the nest completes the process.

The infrared relay installation depends on the physical construction of the nest, the posture of the sitting bird, the size of target it provides and the substrate on which the nest is built. Nests constructed on stable substrate, e.g., most dabbling duck nests, present little difficulty. Two sharpened, metal angle-irons are driven into the soil on a line bisecting the nest cup and the relay is bolted to 1 stake, the reflector to the other. The infrared beam is adjusted by moving the relay and reflector vertically until the beam is broken by the sitting bird's body. The possibility that vegetation or nest materials will block the beam can be reduced by placing the relay and reflector as close as possible to the rim of the nest cup. In addition, small boards can be positioned between the nest cup and the relay and reflector to arrest growth of vegetation. Prior to installation exposed surfaces should be painted to match the colors at the nest-site. Relay installation at overwater nests with an unstable substrate, e.g., nests of most diving ducks, is accomplished by driving 2 metal rods into the marsh bottom. The relay and reflector are then attached to the rods and aligned in the same manner as in the case of a ground nest. When monitoring cavity nesting birds, the relay and reflector are fastened to brackets and aligned so that the bird interrupts the beam when entering or departing.

The thermistor probe is inserted into an egg using a technique similar to that of Caldwell and Cornwell (1975:709). The egg air cell is located with a flashlight and outlined on the egg shell with a pencil; a small (0.8 mm) hole is drilled in the shell at the apex of the air-cell end with a sterile bit, taking care not to perforate the air-cell membrane, and the hole is enlarged with a sterile scalpel to accommodate the thermistor. The probe, dipped in alcohol and allowed to dry, is inserted adjacent to the air-cell membrane and the hole sealed with epoxy glue (Fig. 3). The termistor wire is then taped to the long axis of the egg with adhesive tape. After inserting the probe, the egg is placed in the nest, the probe wire drawn through the bottom of the cup and out the side of the nest. For species in which the egg air cells are too small to accept the probe, e.g., Spotted Sandpiper (*Actilis macularia*), the probe may be glued to the side of an egg, placed in an artificial egg, or fastened to the bottom of the nest.

Unlike the silent, infrared relay, the camera emits a faint click when

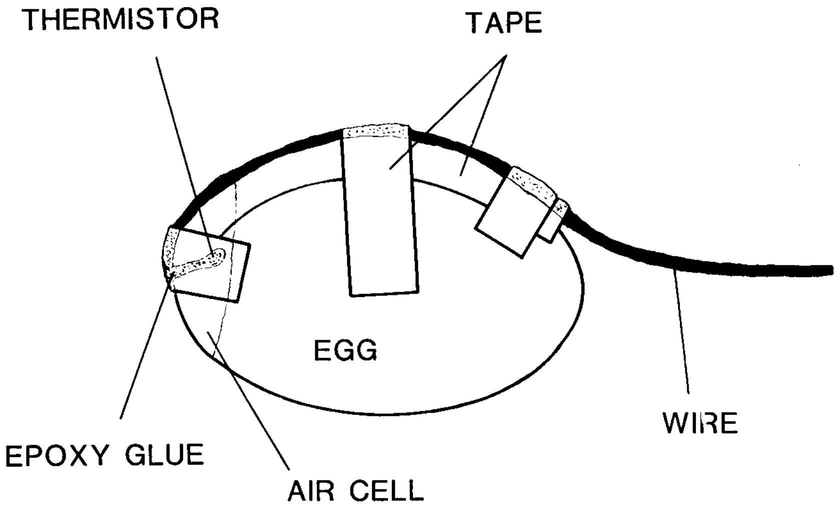

FIG. 3. Diagram of thermistor implantation in an egg.

the shutter releases. Thus, the camera and tripod must be positioned a sufficient distance from the nest to avoid frightening the bird. Because photographic monitoring in independent mode is not continuous, i.e., must be set at a 1–60 sec interval, selection of the shutter release rate is important. If the frequencies of brief activities, e.g., egg turning and preening on the nest, are to be measured, the interval must be less than the minimum duration of these behaviors. A clock placed in the field of view simplifies the film analysis.

For species monitored to date, a chart speed of 5 cm/h allowed measurement of periods on or off the nest to the nearest minute. Chart rolls are 19.2 m long, hence, a paper change is necessary every 15 days. A more rapid speed, attained by a simple and inexpensive gear change, would be necessary for accurate measurement of activities of shorter duration.

The frequency of battery change depends on the condition of the batteries, length of connecting sensor cables and temperature. Using the infrared relay, the thermistor and the camera in dependent mode with 33 m of cable, a single 65 A-h battery will provide power for 4 days; 2 batteries in parallel last 8 days. We found that changes at 2–4-day intervals are best. Replacement of the camera batteries with each film change reduces the possibility of power failure during a monitoring session.

Individual cables or a single multiconductor to the detectors may be used. Cables need not be shielded but must be waterproof and sufficiently durable to withstand months in the field. The infrared relay requires 3

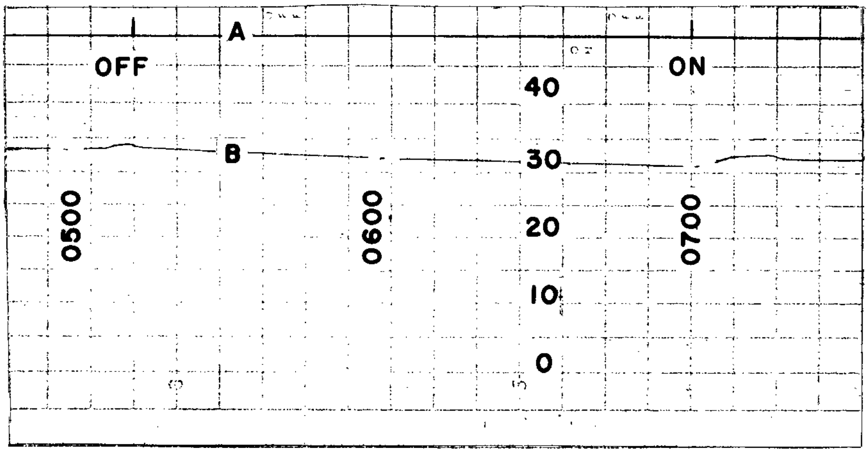

FIG. 4. Three-h recording of the activity of an incubating Wood Duck: (A) event channel showing departure from cavity at 05:16 (OFF) and return at 06:58 (ON) and (B) egg air cell temperature in °C. Breaks in B denote 1-h intervals.

conductors while the thermistor and camera 2 each. By cutting cables into 33 m lengths and using waterproof connectors, one may extend the cable needed to reach the nest from the recorder. The advantage of this is that the added power demand of the longer cable can be easily calculated. The battery must be changed 1 day sooner per 33 m of cable used. Thus, a monitor with two 33 m cable sections would require a battery change every 3 days vs 4 days for 1 with a single section. Cables at and near the nest should be secured by taping or tacking them down, then covered with vegetation or placed underwater.

EXAMPLES AND DISCUSSION

Species monitored employing components of the system include: the Trumpeter Swan (*Cygnus cygnus buccinator*), Canada Goose (*Branta canadensis*), Wood Duck (*Aix sponsa*), Pintail (*Anas acuta*), American Wigeon (*Anas americana*), Gadwall (*Anas strepera*), Green-winged Teal (*Anas crecca carolinensis*), Blue-winged Teal (*Anas discors*), Northern Shoveler (*Anas clypeata*), Lesser Scaup (*Aythya affinis*), Canvasback (*Aythya vallisneria*), Redhead (*Aythya americana*), Ring-necked Duck (*Aythya collaris*), Ruddy Duck (*Oxyura jamaicensis*), Western Grebe (*Aechmophorus occidentalis*), Spotted Sandpiper, Short-eared Owl (*Asio flammeus*) and Sharp-tailed Grouse (*Pedioecetes phasianellus*).

Based on data from 72 nests where the infrared relay and thermistor probe were employed, 32 of 1066 (3.0%) monitored days were lost due to

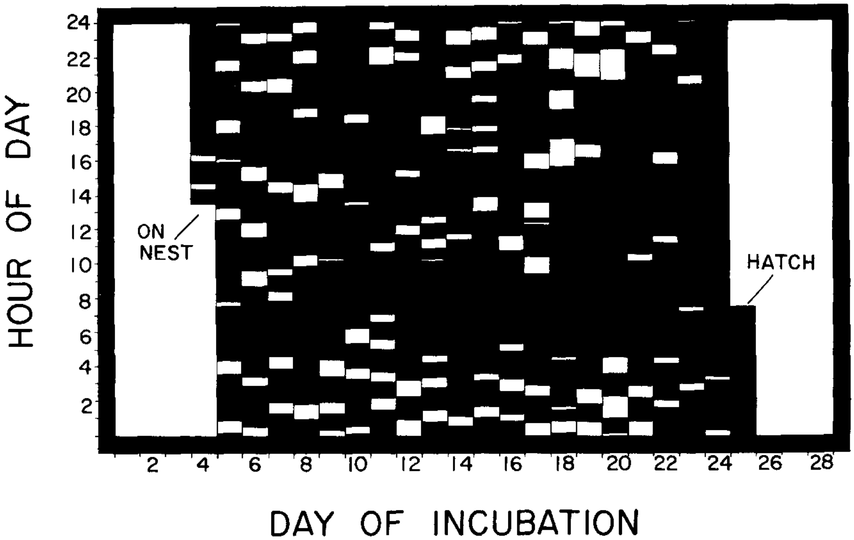

FIG. 5. Example of the nest attentiveness of a Ruddy Duck female, 3–27 June 1975, recorded using thermistor and infrared relay sensors.

sensor or recorder failure. Moreover, no records of inattentive and attentive periods at the nest were lost when using 3 sensors (N = 10 nests, 216 days). Statistical treatment of incubation time budget data is difficult without relatively complete records; therefore, keeping instrument failures to a minimum is important.

The multiple sensor approach not only permits recording of prelaying, laying and incubation time budgets, it also allows synchronous measures of egg air cell and/or nest air temperature and parent bird postures, displays, preening, sleep and other activities at the nest. An example of the recorder output for a Wood Duck recess is given in Fig. 4, and for a Ruddy Duck incubation attentiveness pattern in Fig. 5. Individuals frequenting a nest can be identified on film if markers or unique characters are present.

The cost of a unit with the 3 sensors is about $800 per monitor, and the construction is relatively simple. Except for the infrared relay, recorder, camera and thermistor, all components used in the system may be purchased in most electronic stores. A knowledge of simple DC parallel and series circuits is needed to assemble or repair the interface and time-reference circuits.

The system may have minor disadvantages when used to monitor birds that are disturbed by the thermistor wire attached to the egg or nest, or by changing of the camera film and batteries. We have not encountered the former and have found that 84.1% (N = 44) of the eggs with implanted thermistors have hatched. We suspect that species such as raptors may be difficult to monitor using the thermistor (see Varney and Ellis 1974). But the camera and infrared sensor would provide data in these cases. When the camera must be placed so close to the nest that the sitting bird is disturbed during maintenance, the infrared and thermistor recordings must be carefully studied and the film and batteries changed when the bird is off the nest. This may be done for non-continuous incubating species but not for one in which both sexes incubate or others whose nest is constantly attended.

SUMMARY

The construction and field application of a multiple sensor (photoelectric-thermistor-photographic) system for avian nesting studies is described. The portable, battery-powered system has several advantages over previously described techniques. Foremost is the accurate and continuous recording of incubation time budgets. The system permits synchronous recordings of egg air cell and/or nest air temperature, postures, displays, preening, nest construction, and prelaying and incubation time budgets.

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