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A DEVICE FOR SIMULTANEOUSLY MEASURING NEST ATTENDANCE AND NEST TEMPERATURE IN WATERFOWL

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Abstract.—Previous studies of waterfowl have measured nest attendance and nest temperature separately using a variety of methods. A device was developed that monitors nest attendance and temperature simultaneously. The device consists of an artificial egg with a microswitch that records nest attendance and a thermistor probe that records temperature. Data are stored in a single-channel data logger. The device described measures the length of incubation breaks, and nest cooling and warming rates.

UN INSTRUMENTO PARA MEDIR SIMULTÁNEAMENTE LA ATENCIÓN AL NIDO Y LA TEMPERATURA DE ÉSTE EN AVES ACUÁTICAS

Sinopsis.—En estudios previos se ha medido, para aves acuáticas, el período de atención al nido y la temperatura de éste, utilizando métodos variados. Se desarrolló un instrumento que permite monitorear la atención al nido y la temperatura del mismo simultáneamente. El instrumento consiste en un huevo artificial con un micro-interruptor que informa sobre la atención al nido y un termistor que recoge los datos sobre temperatura. El instrumento mide el tiempo que el ave está fuera del nido, enfriamiento del nido y la tasa de calentamiento.

Incubation patterns of birds have been of interest to ornithologists for over 60 yr (Baldwin and Kendeigh 1927). Waterfowl exhibit a wide range of incubation patterns, from Emperor Geese (*Anser canagicus*) that incubate 99.5% of the day (Thompson and Raveling 1987), to Redheads (*Aythya americana*) that incubate as little as 72.9% of the time (Low 1945). Nest attentiveness and nest temperature have previously been measured numerous ways (see Afton and Paulus 1992 for review). Simultaneous measurement of both nest attendance and temperature, however, has been difficult and expensive (Cooper and Afton 1981).

Simultaneous recording of nest attendance and temperature allows calculation of nest cooling rates during incubation breaks. We developed an economical method of simultaneously monitoring both incubation behavior and nest temperature. We used an artificial egg containing a microswitch to measure nest attendance and a thermistor probe to measure nest temperature. Nest temperature and attentiveness data are stored electronically in a single channel data logger.

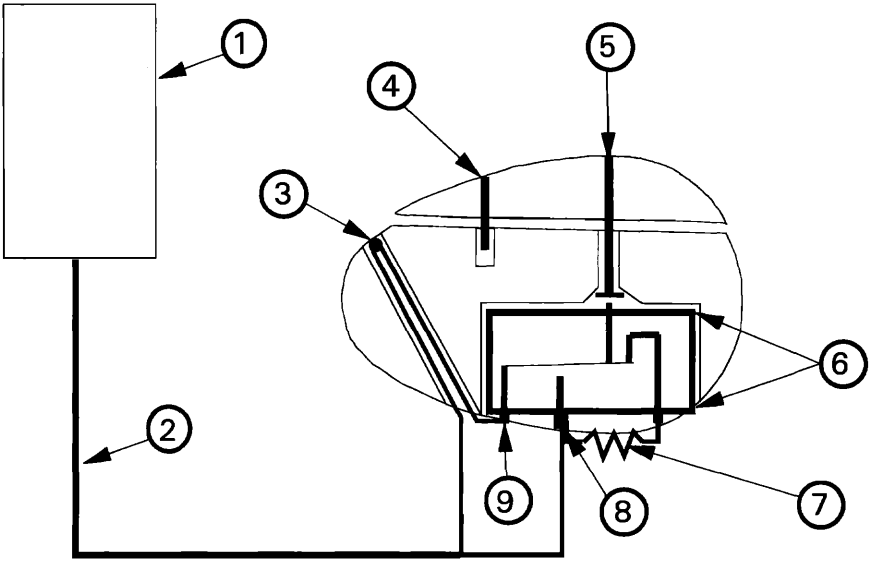

FIGURE 1. Detail of device use to monitor nest attendance and temperature. (1) Hobotemp-XT data logger, Onset Instrument Corporation, Pocasset, Massachusetts. (2) Detachable thermistor probe lead. (3) Thermistor tip. (4) Cap alignment pin. (5) Microswitch activation plunger. (6) Microswitch, (Catalog No. 35-822) GC Electronics, Rockford, Illinois. (7) 10,000 Ω resistor. (8) Normally open terminal. (9) Common terminal.

DESCRIPTION OF DEVICE

Artificial eggs (hereafter EGGS) were constructed of auto body filler poured into egg shells. Small chicken egg shells were used to construct EGGS for use in duck nests; previously collected goose egg shells were used as molds for EGGS used in goose nests. After the body filler hardened in the mold, the egg shell was peeled off. A cap was formed by carefully sectioning the EGG longitudinally, removing one quarter of the EGG with a fine toothed saw (Fig. 1). The cap and base were then painted with a flat finish enamel the approximate color for the target species.

Two sections of stainless steel nail (3.5-mm shaft diameter) were affixed to the cap portion of the EGG. One section of nail acts as a plunger, extending through the EGG to contact a two-position microswitch seated in the base of the EGG; the head of this nail contacts the switch and serves to hold on the cap (Fig. 1). The other section of nail slides in a blind channel and keeps the cap correctly oriented on the EGG (Fig. 1). The gap between cap and base is just sufficient to close the microswitch (approx. 2 mm).

We used microswitches that required 15 g for actuation. We removed the actuating lever and trimmed the switch case so the plunger contacted the actuating post directly. The microswitch was glued into a recessed slot along the bottom of the EGG created by drilling adjoining holes. A 10,000

Ω resistor was soldered across the two accessory terminals of the microswitch. The insulation was carefully removed from a 15-mm section of the thermistor probe lead approximately 40-mm from the thermistor tip. The distance from the tip over which the thermistor lead was exposed varied depending on the desired location of the thermistor probe on the surface of the EGG, and the size of EGG (i.e., longer distances were required for larger eggs). The copper lead was cut and the two ends soldered to the common and the normally open terminals of the microswitch (i.e., connection is open when the switch is up; Fig. 1). Silicon caulk was used to seal the bottom of the EGG.

We drilled two 3.5-mm holes in the bottom of the EGG and tapped 100-mm sections of threaded rod into these holes. These rods served to fix the EGG in the nest and maintain proper orientation, with the cap towards the female. We placed EGGS in the bottom, center of nests. The thermistor lead to the data logger (see below) was run through the bottom of the nest and concealed with vegetation. The thermistor wire was stretched away from the nest, and attached to the data logger which was placed in a plastic bag and tied to a stake nearby.

We used a single channel data logger to record data from the EGGS (Fig. 1). Data are stored in non-volatile, erasable, programmable, read-only memory (EEPROM). The data loggers can be set to record temperature at a variety of intervals from 0.5 s to 4.8 h depending on the expected behavior of the study species and the desired time of uninterrupted recording. We used intervals of 2 and 4.8 min. Memory is available for 1800–32,000 points (cost $99–216 US). Thermistor leads are available in lengths of 0.3–15 m (cost $18–36 US). Software to configure and initiate the data logger, check the system, and download the data are also available (cost $59 US).

When the female is on the nest, the cap is depressed (incubated mode), the plunger trips the microswitch, current flow is directed to the thermistor only and the data logger records the temperature in the nest. When the female is off the nest, the cap is released (unincubated mode), current flow is directed through both the resistor and the thermistor, and a modified temperature is recorded. This constant resistance, added when the female is off the nest, results in an easily identifiable reduction in the recorded temperature (Fig. 2).

DATA TRANSFORMATION

The additional resistance added by the microswitch when the female is off the nest results in a marked decrease in the recorded temperature. Thus, the data recorded when the female is off the nest must be transformed to actual temperature. The relationship between temperature and resistance is not linear (Fig. 3), thus the additional resistance added when the female is off the nest does not equate to a fixed temperature difference. The actual nest temperature when the female is off the nest is calculated by subtracting the additional resistance (Fig. 3). To remove the

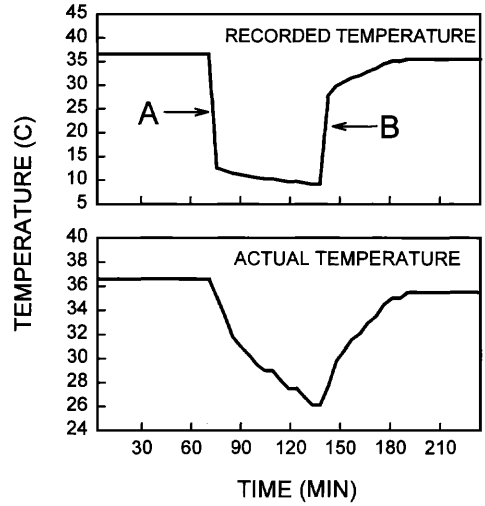

FIGURE 2. Recorded and actual temperatures of a Northern Shoveler nest during a typical nest break. (A) represents the artificial drop in temperature caused when the female left the nest. (B) represents the subsequent artificial increase in temperature when the female returned. The actual temperature graph shows the transformed temperature pattern for the same period.

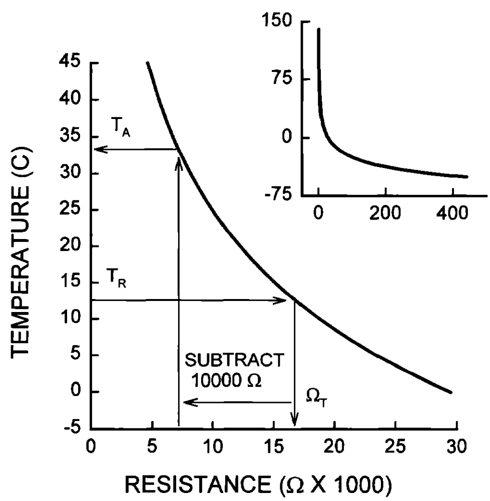

FIGURE 3. Relationship between resistance and temperature described by equation 1. Arrows demonstrate the data transformation process for a recorded nest temperature (T_R) of 12 C when the female is not on the nest (actual nest temperature (T_A) was 33 C). Inset shows the relationship between resistance and temperature over the entire range of the thermistor.

additional resistance, the total resistance (Ω_T) is calculated from the recorded temperature (T_R) as:

$$\Omega_T = 27983.087372 \cdot e^{-0.04746 \cdot T_R} + 1418.35991. \quad (1)$$

Given this total recorded resistance, the additional 10,000 Ω are subtracted and the actual temperature (T_A) is calculated as:

$$T_A = \ln\left[\frac{(\Omega_T - 10{,}000) - 1418.359911}{27983.087372}\right] \Big/ -0.047460. \quad (2)$$

A computer program that performs the data transformation on the raw-data transfer files from the data logger is available from the authors.

METHODS OF TESTING THE DEVICE

During the summer of 1993, we monitored 66 nests of various waterfowl species with EGGS. We tested EGGS in duck nests on Minto Flats State Game Refuge (64°50′N, 148°50′W) and in goose nests on the Yukon Delta National Wildlife Refuge (61°20′N, 165°35′W). Field testing was accomplished with appropriate permits for each study area. Nineteen of the nests sampled (29%) had EGGS placed in them during the laying period. Species monitored included: Northern Shoveler (*Anas clypeata*), Lesser Scaup (*Aythya affinis*), Greater Scaup (*Aythya marila*), American Wigeon (*Anas americana*), Black Brant (*Branta bernicla nigricans*), and White-fronted Goose (*Anser albifrons*). We randomly selected five EGGS used in Northern Shoveler nests and placed them in a drying oven and allowed them to equilibrate. The oven temperature was monitored with a standard (unmodified) thermistor probe. We switched EGGS between incubated and unincubated modes and recorded both the actual and modified temperatures. This switching allowed comparison of temperatures among EGGS in a constant environment and comparison of transformed temperatures (removing the additional resistance, simulating absence of the female) with actual probe temperature. We varied the drying oven temperature over the observed range of normal nest temperatures 25–40 C and allowed EGGS to equilibrate for several hours at each setting prior to recording data. We used a two-way analysis of covariance with eggs and incubation mode as factors and oven temperature as a covariate to test for differences in temperatures among EGGS and differences between actual and transformed temperatures.

RESULTS

We did not detect any nest abandonment due to the presence of the EGGS during laying or incubation as all females returned to their nests and incubated the artificial EGGS. On three occasions, Lesser Scaup hens pushed the EGG out of position which resulted in the cap being held down by adjacent eggs.

There was no difference between the actual and transformed temperatures ($F_{1,133} = 0.09$, $P = 0.7670$). The average difference between the corrected and actual temperature was 0.014 C (range −0.75–0.66 C). There was no difference among eggs in the temperatures recorded in a constant environment ($F_{4,130} = 1.96$, $P = 0.1049$).

DISCUSSION

We believe EGGS are a valuable tool for collecting data on female attentiveness and nest cooling rates. Important features of this device are its simplicity in use, flexibility in collecting data and low cost.

The success of EGGS is related to the egg rolling behavior of the study species. Several Lesser Scaup females forced the EGGS out of position. In most cases the spikes extending from the bottom of the EGG were sufficient to prevent this problem. Alternatively, we suggest experimenting with one anchor rod attached near the center of the EGG. This anchor would allow the EGG to rotate around a vertical axis and may satisfy the female that egg rolling has been successful. We recommend repositioning the EGGS every few days or whenever the data logger is downloaded to avoid data errors associated with EGG position.

Although the design of the EGG is quite simple, care must be maintained during construction. If the holes for the plunger and guide pin are not parallel the cap will tend to stick. Additionally, 15-g microswitches were too light for the goose eggs we built, resulting in failure to record some incubation breaks. We suggest using heavier actuating switches in goose EGGS.

The system is quite accurate in recording nest temperature when the female is incubating. The data loggers and probes are accurate to ±0.2 C and were unaffected by our modification. The accuracy of the system degrades slightly when the female is off the nest as some additional error is caused by the temperature transformation. The average deviation of the transformed temperature from the actual was small, but the range of this error should be considered. All of our transformed temperatures fell within ±0.75 C of the actual temperature, and 80% of the observations fell within ±0.5 C. Thus, the inherent error in the data logger system is magnified during transformation; a 0.2 C difference at 12 C expands to a 0.55 C difference when transformed. The accuracy of the transformed data should be assumed to be no better than ±0.75 C.

The data loggers are available with fixed or detachable thermistor probes. We used detachable probes so that probes would pull out if a predator removed the EGGS, and data loggers and data would not be lost. On several occasions during our study, however, failure of the probe to make complete connection resulted in no data being recorded. A portable computer can be used to test for proper connection and thereby avoid this problem. Researchers should consider the trade-off of potential failure with the removable probe and potential data logger loss with the fixed probe. Additionally, the data loggers are available in several different memory sizes. Researchers must consider the expected behavior of the study species (i.e., nest break length) and the desired time of uninterrupted recording when selecting the appropriate data logger memory size. Species taking short incubation breaks will require short sampling intervals to detect and define the length of incubation breaks. For some species the 15-m thermistor lead will allow data to be downloaded without disturbing the female allowing longer periods of uninterrupted behavior to be recorded.

The temperatures recorded by artificial eggs may not be representative of internal egg temperatures of viable eggs (Afton and Paulus 1992). Additionally, the cooling and warming rates of artificial eggs may not be representative of actual egg cooling and warming rates. The rates of temperature change in artificial eggs, however, is likely correlated with actual rates of egg temperature change. The relationship between artificial and actual egg temperature change rates could be estimated using an additional thermistor probe placed in the air cell of a viable egg (Cooper and Afton 1981). Alternatively, an EGG could be constructed with the thermistor tip left loose and placed in the air cell of a viable egg. This modification would allow measurement of actual egg temperatures and nest attendance simultaneously.

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