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A COMPARISON OF THREE TECHNIQUES FOR MONITORING AVIAN NEST ATTENTIVENESS AND WEIGHT CHANGE

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Abstract.—Many systems are used to monitor nest attentiveness and weight change of incubating birds, but few studies have directly compared different systems under the same environmental conditions. In this study, three systems that measure these variables for cavity-nesting waterfowl were designed and compared, and were tested in the laboratory and in the field. The plunger system is a mechanical monitor that was sensitive to humidity and proved ineffective in the field, but would be useful in controlled environment studies. The load cell system and the balance system are electrical systems that provide reliable, accurate measurement of nest attentiveness and weight change and can be set up in the field to operate unattended for more than a week at a time. The installation procedures, merits and limitations of each of these systems, as well as the possible lethal effect of the balance system on developing embryos, are described.

COMPARACIÓN DE TRES TÉCNICAS UTILIZADAS PARA MONITOREAR LA ATENCIÓN AL NIDO Y EL CAMBIO EN PESO DE AVES QUE INCUBAN

Sinopsis.—Se han utilizado muchos sistemas para monitorear la atención al nido y cambio en peso de aves que incuban. Pero pocos estudios han comparado directamente diferentes sistemas bajo las mismas condiciones ambientales. En este trabajo se diseñan y comparan tres sistemas para medir las variables antes mencionadas en Anseriformes que anidan en cavidades. Se prueban los sistemas tanto en el campo como el laboratorio. El "sistema sumergible" es un monitor mecánico que resulta sensitivo a la humedad y por consiguiente inefectivo en el campo, aunque no asi en el laboratorio. El "sistema de balance" y el de "cerda recargable," ambos sistemas eléctricos, tomaron por más de una semana medidas precisas y confiables de la atención al nido y cambio en peso. Se describen los procedimientos de instalación, méritos y limitaciones de cada uno de los sistemas. Además, se discute el posible efecto letal del sistema de balance en los embriones en desarrollo.

Information acquired by monitoring avian nesting behavior can be used to address many questions in biology (Cooper and Afton 1981). For example, biologists monitor nest attentiveness and weight change during incubation to study parental investment. Techniques used to measure nest attentiveness range from visual observations (e.g., Van Vessem and Draulans 1986) and time lapse cameras (e.g., Cartar and Montgomerie 1987) to telemetric eggs (e.g., Varney and Ellis 1974) and radio-equipped birds (e.g., Licht et al. 1989). Few studies, however, use techniques that monitor nest attentiveness and weight change simultaneously (e.g., Jones 1987). Although merits and limitations of some systems have been discussed previously (Cooper and Afton 1981, Licht et al. 1989), these studies did not directly compare the various systems under similar field conditions.

Our goal was to measure simultaneously daily changes in weight and nest attentiveness of female Common Goldeneyes (*Bucephala clangula*), a cavity-nesting duck that breeds in the boreal forest. Our review of existing techniques indicated that none satisfied our requirements. For example, systems relying on monitors that transmitted information to a central receiver were inappropriate because the topography in our study area would limit long-range transmission. Similarly, systems such as video monitors were unsuitable because mounting a camera on the side of a nest box 3 m up a tree and providing sufficient power for long-term monitoring were not practical in our remote study area. We required a system that could be installed quickly, could rely on its own power supply for periods of a week or more and could withstand harsh, variable weather. Thus, we designed three remote monitoring systems that could be installed in existing nest boxes to record female behavior unobtrusively. Although each system was designed for use in nest boxes, two of the techniques can be easily adapted to ground-nesting species. In this paper we describe the components, function, merits and limitations of each system and compare them to one another.

METHODS

We conducted the study in 1989 and 1990 on Common Goldeneyes nesting in previously established nest boxes in an area 50 km northeast of Sudbury, Ontario. Approximately 70 nest boxes (22 × 25 × 47 cm) were available in each year. Nest boxes were erected on large trees (diameters >25 cm) at heights >3 m. We designed and tested three monitoring systems: the "plunger system," the "load cell system" and the "balance system." During field trials, we installed the systems in occupied boxes in the period from egg-laying through the first 14 d of incubation. Monitoring systems operated continuously until the system failed, the nest failed or until incubation was completed.

The plunger system was encased in a separate wooden box (24 × 28 × 20 cm) and attached to the bottom of the nest box (Fig. 1). We used six of the plunger systems. A nest platform fit snugly inside the box (but was free to move vertically) and was attached to a nylon dowel that extended through a 2.5-cm diameter hole drilled through the bottom of the nest box into the monitor chamber, forming a plunger. Tension on the plunger was maintained by a small spring (1.25 × 5 cm). To record the mass on the plunger, a pencil was attached to the plunger to trace a line on a moving strip of cash register paper. A Tachograph disc recorder (which works like a clock motor and is normally used to record information in commercial trucks) powered by a 6-V lantern battery moved the paper at a constant speed.

We used five load cell systems (Fig. 2) obtained from the Ontario Ministry of Natural Resources. A load cell consisted of four strain gauges linked to a weighing platform that were calibrated and installed inside an occupied nest box. To record measurements of weight change on the platform we ran a cable to a Rustrak strip recorder (model 288; chart speed 2.5 cm/h) housed in a waterproof container. The container was placed approximately 10 m behind the nest tree. The Rustrak recorded mass from 500 to 2500 g and was fitted with an alternator to control current and give accurate operation from a 12-V DC battery. The power

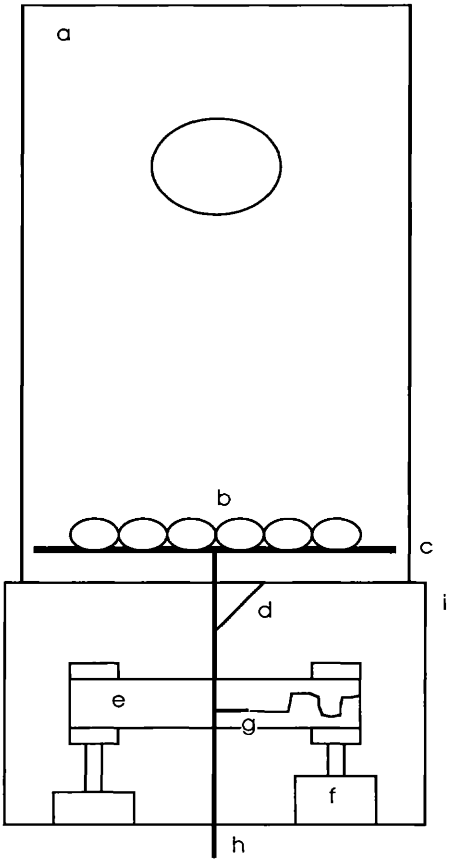

FIGURE 1. A schematic diagram of the plunger incubation monitoring system. System components are as follows: a = nest box, b = eggs, c = platform, d = spring, e = recording paper, f = tachometer motor and batteries, g = pencil, h = nylon dowel (plunger), i = monitor housing.

supply was a 12-V, 24-A/h rechargeable battery (YUASA model NP24-12) that was recharged by two 46 × 58 cm solar panels, each capable of charging at 1 A/h. Installation of the system required drilling only a single small hole in the nest box through which to pass the cable.

We used six sets of the balance system (Fig. 3) that consisted of an electronic balance (A&D Engineering model EW3000B) accurate to 1 g (range 0–3000 g) installed inside a nest box. Two cables were attached to the balance; one was connected to the battery, and the other was connected to a printer (A&D Engineering model AD 8117) to record mass on the balance platform. The printer and battery were housed in a waterproof container 10 m behind the nest box, and were powered by a rechargeable 12-V, 24-A/h battery that was recharged by a single, 46 ×

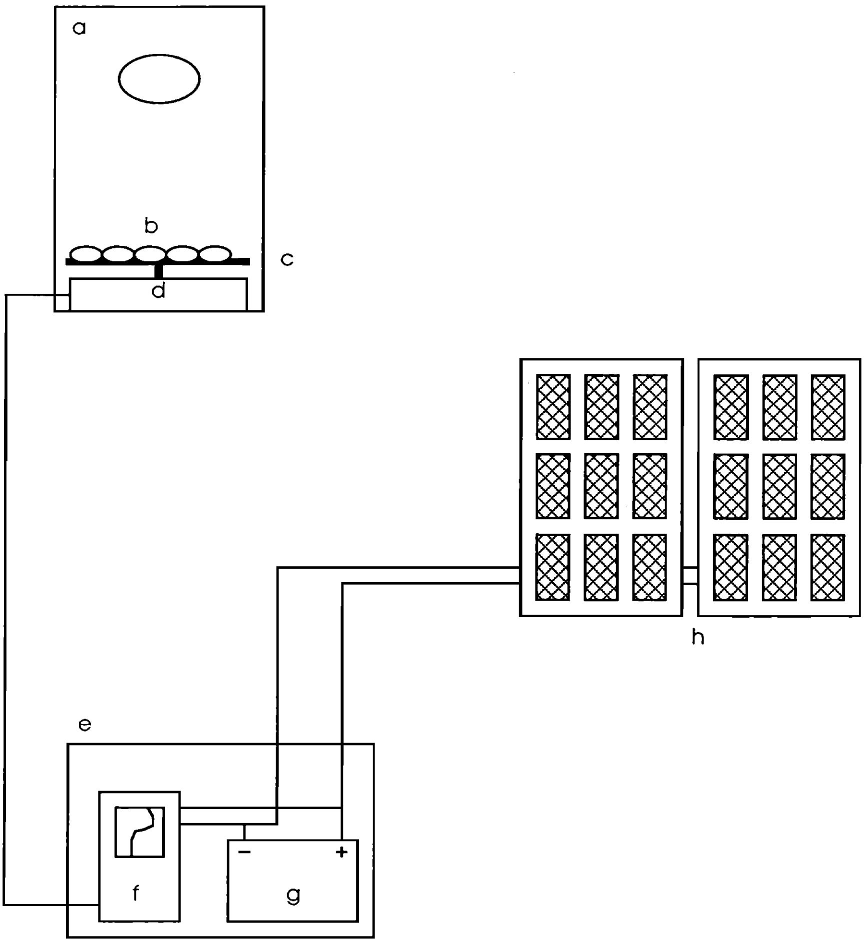

FIGURE 2. A schematic diagram of the load cell monitoring system. System components are as follows: a = nest box, b = eggs, c = platform, d = load cell, e = monitor housing, f = Rustrak strip recorder, g = 12-V battery, h = solar panels.

58 cm, 1-A/h solar panel. We designed and attached a small timer, powered by eight D-cell alkaline batteries, to the printer, and set the timer to print a recording at approximately 6.5-min intervals (this interval was adjustable).

Before the breeding season, we tested the systems in indoor and outdoor trials, and evaluated their performance during the breeding season. Each plunger system had two laboratory trials (duration 14 d and >30 d) and one field trial, whereas each load cell system had one laboratory trial (until battery failure) and two field trials, and each balance system had one laboratory trial (duration 5 d; two were tested until battery failure)

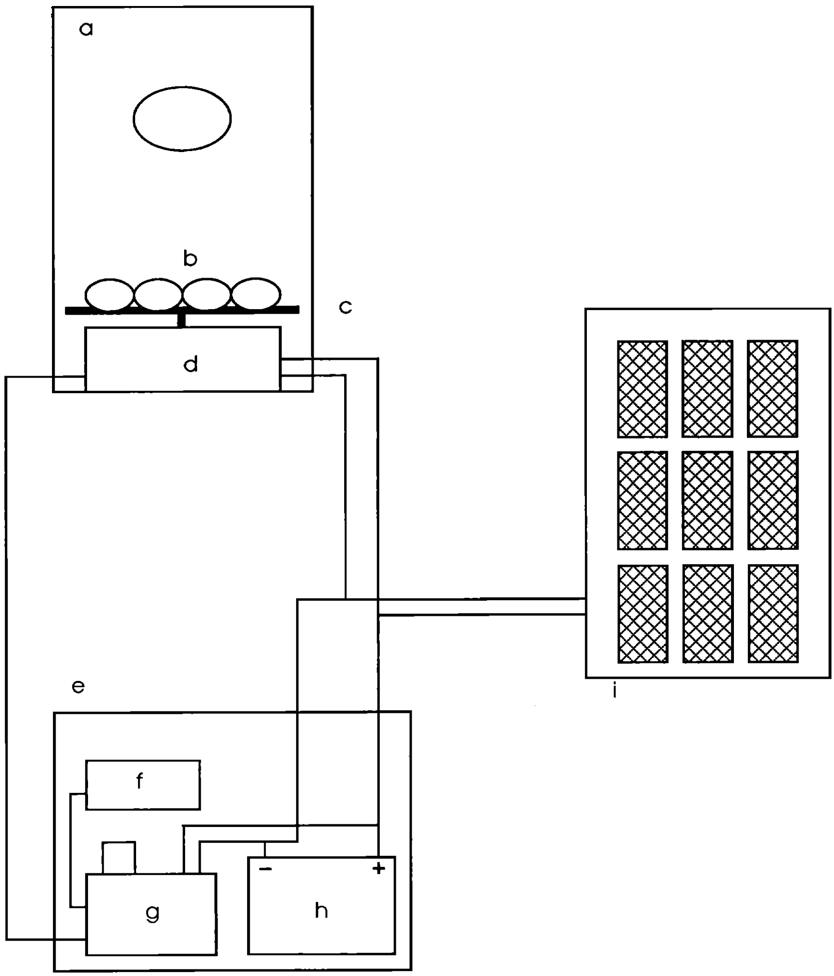

FIGURE 3. A schematic diagram of the balance monitoring system. System components are as follows: a = nest box, b = eggs, c = platform, d = electronic balance, e = monitor housing, f = timer, g = printer, h = 12-V battery, i = solar panel.

and two field trials. We assessed 10 practical aspects of each system: box alterations (modifications to the nest box necessary to install the system); installation time (time required for one person to install the ground components of a system, and for a second person to install nest box components); fragility (subjective assessment of susceptibility to damage for the system during transport in the field); audible noise (noise of the system that might influence female behavior); trial running time (minimum time that a system operated continuously); field running time (mean time that a system continuously recorded behavior in the field); visit

TABLE 1. A comparison of the characteristics of each monitoring system. For ranked scores (in parentheses), "1" refers to the best system for the variable and "3" refers to the poorest system. Note that values for the field running time are conservative measures because operating systems were shut off if a female abandoned or if the eggs hatched.

Variable	System: Plunger	Load cell	Balance
Required alterations to nest box	(3)	(1)	(2)
Installation time (min)	>60 (3)	30–45 (1)	45 (2)
Fragility for field transport	(1)	(2)	(3)
Audible noise of system	none (0.5)	loud click (3)	none (0.5)
Trial running time (d)	>30 (1)	14 (3)	21 (2)
Field running time ($\bar{x}$ ± SE d)	8.8 ± 5.3 (3)	9.8 ± 1.9 (1.5)	10.4 ± 1.7 (1.5)
Required visit frequency	1/7 d (0.5)	1/7 d (0.5)	1/4 d (3)
Accuracy of recorded measurements (g)	±50 (3)	±10 (2)	±1 (1)
Susceptibility to inclement weather	(3)	(10)	(2)
Cost per system ($US)	175 (1)	2610 (3)	1570 (2)

frequency (interval between visits required to ensure proper function of the system); accuracy (assessed by repeated measurements of a known mass); susceptibility to weather (a qualitative evaluation of the performance of a system during high humidity or precipitation); and cost (approximate cost of each system in 1989 $[US]). Also, we noted special problems or benefits associated with the various systems in the field.

RESULTS AND DISCUSSION

The plunger system was effective in controlled trials, but was not effective in the field (Table 1). Humidity caused the recording paper to adhere to itself and not move as required. Also the plunger system was difficult to retrofit to existing nest boxes. Installation of each of the three systems was slow because only one person could work up the tree (attached by a climbing belt), but installation of the plunger system was slowest because of the number of modifications required to attach the monitor housing to the nest box (Table 1). In one instance this delay caused a female to abandon the nest. Although this system provided reliable measurement of nest attentiveness, it gave coarse measurement of female and nest mass. Despite these limitations, this system is inexpensive, an important consideration for many studies, and it may be best suited for laboratory monitoring of the nest attentiveness of many subjects.

The load cell system was the most expensive system, and used considerably more power than the other systems (thereby requiring two solar panels for recharging; Table 1). This system was effective under all weather conditions, gave a continuous, accurate measure of nest attentiveness, and gave accurate measures of mass on the load cell (Table 1). It required few modifications to existing nest boxes for installation, and could be installed quickly in the field. Furthermore, an entire incubation period could be recorded on a single roll without requiring paper changes. A minor limitation of this system was that a "click," audible up to 10 m, was produced during Rustrak operation (approximately one click per second), requiring the recorder to be situated away from the nest to minimize disturbance to the incubating female.

The balance system was less expensive and used less energy than the load cell system, and measured mass most accurately (Table 1). By adjusting the timer interval, nearly continuous monitoring of nest attentiveness could be achieved (i.e., weights could be taken as often as 1 min intervals, although this would draw more power). If the nest or bird moved when a mass was recorded, however, a "*" rather than a weight would be printed. This could present difficulties on windy days if the nest box is mounted on a tree that sways. Two balance systems stopped during a thunderstorm, probably because water entered the nest box. After they were reset, they functioned properly for the duration of incubation. This system was the most fragile system, because internal components could easily break if the balance was dropped, but it was easily transported in a backpack when the balance was protected by foam packaging, and no damage ever occurred. As the system was fragile and two holes had to be drilled in the nest box, it took more time to install the balance system than the load cell system. Also, the printer paper is not rolled by the printer so that the paper falls into the waterproof container. In our study, paper filled the available space and jammed the printer if it was not collected every 4 d. This jamming could be overcome by using a larger container.

Two major limitations are common to the load cell and the balance system. First, the components of both systems must be sized to fit in the nest box, and available balance or load cell sizes may reduce the applicability of these systems for monitoring of some species. A second limitation is the long cables required to power and relay data in these systems. Special care must be taken to lay the cables along the ground so they are not disturbed by large animals, and cables may require covers or repellents to reduce chewing by small mammals.

A potentially serious drawback of the balance system was the apparent effect it had on developing embryos. Of the seven females monitored with this system in 1990, four had no hatching success. Three of the four unsuccessful nests were monitored from >1 d prior to initiation of incubation, whereas the successful females were monitored from later in the first week of incubation. One possible explanation is that the electric field around the balance may have interfered with the field created by the developing primitive streak in the egg (Jaffe and Stern 1979). If embryos were damaged very early in development by this system, they still developed until late in incubation and then died. We observed live embryos in the unsuccessful clutches as late as day 26 of a 30-d incubation period. As embryo development seems to proceed until late in incubation, affected females are apparently unaware of the problem, because both nest attentiveness and weight change of these females was similar to that of unaffected females. Thus, data obtained on these females appeared to be reliable. The possible effects associated with this system warrant further study, and we suggest caution with the use of the balance system in studies where hatching success is an important variable.

CONCLUSIONS

The plunger system requires design alterations to be reliable in the field, but this system does have useful applications for laboratory or controlled-environment studies. The load cell and balance systems provide reliable, accurate data on nest attentiveness and weight change of incubating birds. They can be modified to monitor ground-nesting species, and both are considerably less expensive than multiple sensor systems previously used to record nest attentiveness (e.g., Cooper and Afton 1981). Smaller versions of these two systems should be appropriate for monitoring nesting behavior of other birds such as passerines (e.g., Jones 1987). If the primary goal of a study is to monitor nest attentiveness, then the load cell is the more appropriate system; conversely, the balance system is more suitable for studies where the primary focus is recording the weight change of incubating birds.

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