iButton® Temperature Loggers Effectively Determine Prairie Grouse Nest Absences

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ABSTRACT—Recent technological innovations allow the monitoring of avian nest attendance in ways that reduce disturbance and expense without altering nesting activities. Yet the efficacy of these techniques to assess nest absences has not been determined for ground-nesting prairie grouse. We sought to determine the timing of nest absences by means of accurate detection without intrusive human visitations technology. During the nesting season (May and June), we inserted iButton® Thermochrons (Maxim/Dallas Semiconductor Corp., Sunnyvale, CA) into active greater prairie-chicken (*Tympanuchus cupido*) nests in the Sandhills of Nebraska, USA. We simultaneously monitored the nests with solar-powered video cameras to determine if the lower-cost iButtons would record noticeable changes in nest bowl temperature when video indicated a hen absence. Our data showed that iButtons detected 88% of nest absences in 49 off-bouts (instances of nest absence) and accurately portrayed the length of absence from the nest. In total, average lag time, departure lag time, and arrival lag times were detected by iButtons less than 2 minutes after the actual time recorded by the camera. We also obtained valuable information regarding the timing of hen absence, predation events, and optimal iButton recording intervals. Our study suggests that iButtons could be effectively used to monitor absences at greater prairie-chicken and likely other species of prairie grouse nests in future studies.

Key Words: iButton, nest absence, nest monitoring, nest predation, prairie grouse

Introduction

During incubation, birds must balance the requirement to attend the nest for proper embryological development with the need to leave the nest and forage to meet nutrient intake requirements (Webb 1987; Conway and Martin 2000). Each time a bird leaves its nest, the nest microclimate changes temperature and the nest is more susceptible to predation. Furthermore, nest attendance patterns can influence seasonal nest success, energetic costs of incubation, and lifetime reproductive success (Clutton-Brock 1991). Knowledge of nest attendance patterns could help inform resource management decisions by establishing when a predation event or nest abandonment occurred or how nest attendance is affected by habitat type or other extrinsic disturbances.

A wide variety of methods to monitor nest attendance of birds has included such techniques as direct observation (Norment 1995), video (Cox et al. 2012), electronic balance (Becker et al. 1997), transponders (Kosztolányi and Székely 2002), and thermocouples (Schneider and McWilliams 2007). A number of disadvantages limit the widespread applicability of these techniques, including the monetary expense of direct observations and video camera systems (Hoover et al. 2004), increased predation rates due to video surveillance (Cox et al. 2012), and time required to review video. Recent technological advancements in nest monitoring equipment have allowed for remote monitoring of nest temperature (Richardson et al. 2009; Sutti and Strong 2014); however, the efficacy of such techniques to assess nest attendance has not been determined for obligate grassland ground-nesting birds such as prairie grouse.

Previously, iButtons (Maxim/Dallas Semiconductor Corp., Sunnyvale, CA, http://www.maxim-ic.com/) have been used successfully with ground-nesting birds to determine the onset of incubation and occurrences of nest abandonment or predation (Hartman and Oring 2006; Schneider and McWilliams 2007; Wilson and Martin 2010). For example, when ground-nesting shore-

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birds' nest attentiveness was measured with iButtons, researchers were able to effectively determine when nest incubation was terminated due to abandonment or predation for both exposed nests of piping plover (*Charadrius melodus*) on beaches (Schneider and McWilliams 2007) and less-exposed nests of long-billed curlew (*Numensis americanus*) in grasslands (Hartman and Oring 2006). Although patterns of nest attendance have been estimated with iButtons, use has been primarily limited to the relatively closed environment of cavity nests (Cooper and Mills 2005; Zangmeister et al. 2009; Cooper and Voss 2013; Ellenberg et al. 2015). Further investigation of the capability of this nest monitoring technique with a species of obligate grassland ground-nesting bird is crucial to aiding population management and monitoring programs of grassland birds. To better understand the key demographic parameter of nest survival that may regulate productivity and the growth or decline of populations of greater prairie-chicken (*Tympanuchus cupido*; hereafter, prairie-chickens) (McNew et al. 2012), we provide some insight into how iButtons can be used to monitor nest attentiveness of this ground-nesting grassland bird. Our goal was to determine the effectiveness of iButton® data loggers to detect prairie-chicken hen absences and to document the length of absences. Time of day of hen departures from nests and video footage of nest predations and hen behaviors also were recorded.

Methods

Our study site was in the eastern Sandhills of Nebraska (Rock and Brown Counties), USA. Prairie-chicken hens were collared with radio transmitters in late March and then followed throughout the nesting season in order to locate nests. We inserted two dime-sized (16-mm-diameter, 6-mm-thick, 2.9 g) temperature loggers (iButton Thermochrons DS1921G-F5) into the nest bowl and lightly covered each iButton with nesting material (forbs and grasses) for 3 active nests during the peak nesting season (May and June) of 2011 to record nest temperatures. iButtons are small, self-contained thermal data loggers that record and store temperature data (range = −40° to 85°C) at intervals set by the researcher. Animal research protocols were approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee (Protocol #05-02-007).

A digital video recorder (Archos® AV340) coupled with a weatherproof infrared-capable camera (Supercircuits® PC1841R; shell: 6 cm × 5 cm × 5 cm; 8 LEDs) to capture video images (30 fps) was placed at each nest with iButtons in May and June. Video cameras were placed 0.25–1.37 m off the ground facing the nest at a distance of 1 m. This elevated approach to filming was beneficial in that vegetation did not obstruct footage of the nest, and minor grass movements did not frequently trigger the motion sensor. Black electrical tape was placed on the video camera lens to limit the white light emitted by the infrared night-vision sensors from washing out the view of the nest. Video files were stored and analyzed following the methodology of Powell et al. (2012).

The video cameras recorded the actual length of hen absences and were used to assess the accuracy of iButtons. The length of a hen absence, according to the iButton, was determined from the temperature data. Absences were considered correctly identified by an iButton if there was a significant fluctuation in nest temperature (≥2.8°C) in a relatively short period of time (<1.5 hours). Average lag times were calculated and represent the net number of minutes that an iButton deviated from the actual length of a hen absence as recorded by the video camera.

iButton hen departure time was determined to be the time stamp (iButtons record the temperature at set intervals of minutes) just before the temperature began to rise or fall (Fig. 1). During an absence, temperatures usually reached a maximum or minimum and then began to gradually return to normal. The time stamp recorded just before the maximum or minimum temperature was deemed the iButton hen arrival time. iButton departure and arrival lag times were calculated and represent the net number of minutes that an iButton deviated from the actual hen departure or arrival time. Negative values indicate iButtons recorded the hen departing from or arriving at the nest before the actual time, while positive values indicate iButtons recorded the hen departing from or arriving to the nest after the actual time. A correlation analysis was used to compare absence duration as recorded by iButtons and cameras.

The video and iButton data were analyzed and the total number of unprovoked absences over the span of the study were grouped into daily time periods. Provoked absences were documented instances when incubating hens were flushed from the nest as a result of either human or wildlife influence, whereas unprovoked absences were recorded instances when hens left nests without being flushed by human or wildlife influence. Linear regression in the programming language R (R Founda-

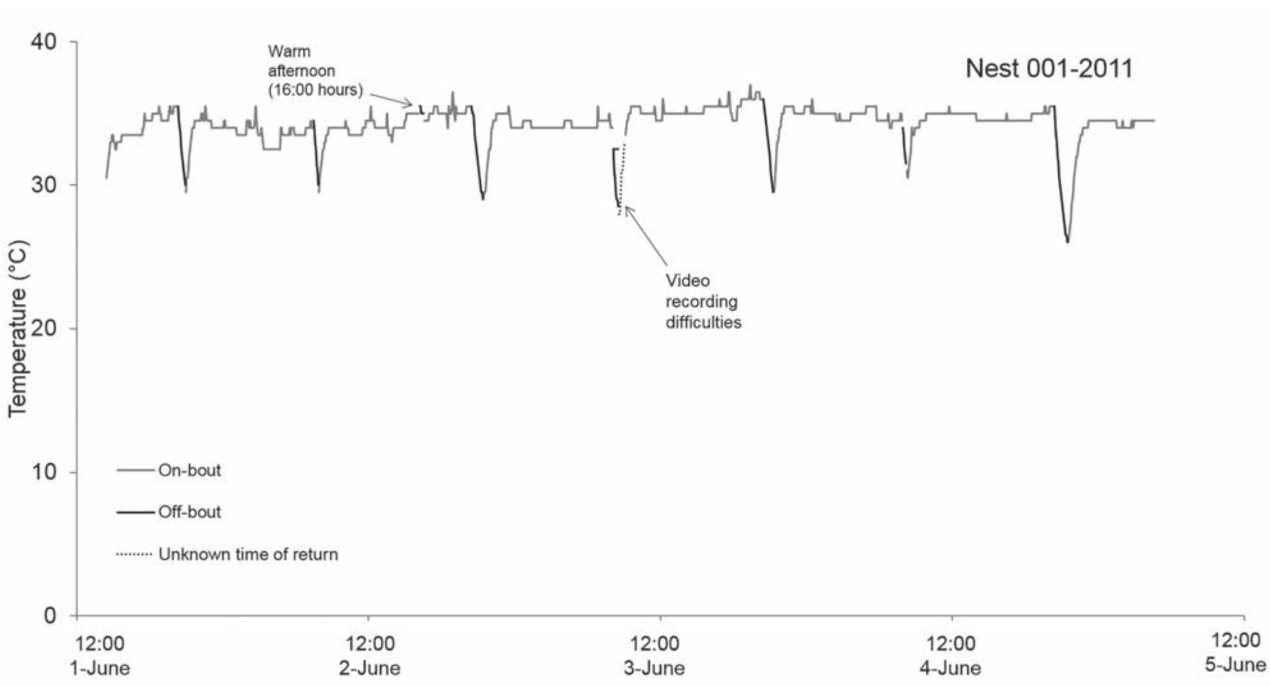

Figure 1. iButton temperature data for a greater prairie-chicken hen nest (#001) over an 88-hour period in Brown County, Nebraska, USA, between May and June, 2011.

tion for Statistical Computing) was used to determine iButton efficacy in correctly identifying nest absences detected by video camera. We analyzed duration of nest absence detected in video recordings to explain the variation in matched time periods of absences detected by the iButtons. In addition, we documented hen behaviors and predation events. A "control camera" was placed at random at the study site between 23 June and 7 July at a height of 0.25 m to test for the artificial effect of predator attraction to the cameras, which could indirectly affect frequency and/or length of hen absences in our study. We placed a single "control" iButton 1 m outside nest #001 at ground level to monitor ambient temperature for 14 days (23 June to 7 July 2011).

Results

We studied three nests: #001 between 30 May and 8 June, #362 between 16 and 20 May, and #542 between 16 and 24 May 2011. A total of 49 unprovoked hen absences were recorded by either iButton or video data over the course of the study. During an absence, iButton data generally recorded a rapid change in temperature. iButtons correctly identified 43 (88%) hen absences, with failed detections occurring on days that were ≥35°C (Table 1). iButtons were also accurate in portraying length of absence from nest (~1-minute average lag time, $F_{1,28} = 119$, $P < 0.0001$, adj $r^2 = 0.80$; Fig. 2). In total, average lag time, departure lag time, and arrival lag times were detected by the iButton less than 2 minutes after the actual time recorded by the camera. Average nest temperature spanned 21° to 33°C, with nest #001 showing the highest average temperature over the 9-day monitoring period. Nest checks found that no eggs were damaged by iButtons. The control camera did not record evidence of predators in the immediate area. Hens generally departed the nest just before sunset and after sunrise (Fig. 2).

Nest #001 started incubation on 21 May and iButton monitoring spanned 9 days (30 May to 8 June). Video of the nest showed that it was depredated by a bull snake (*Pituophis catenifer*) on 8 June 2011 following a struggle between the snake and hen (see video footage: https://youtu.be/DiO22U-R6JA and https://youtu.be/U3T-tKmJ-k1g). The next day the hen was found deceased yet physically intact ~3 m away from the nest. Prior to the depredation event, a hailstorm producing golf-ball-sized hail on 30 May likely detached the power cable of the video camera from the solar panels (see video foot-

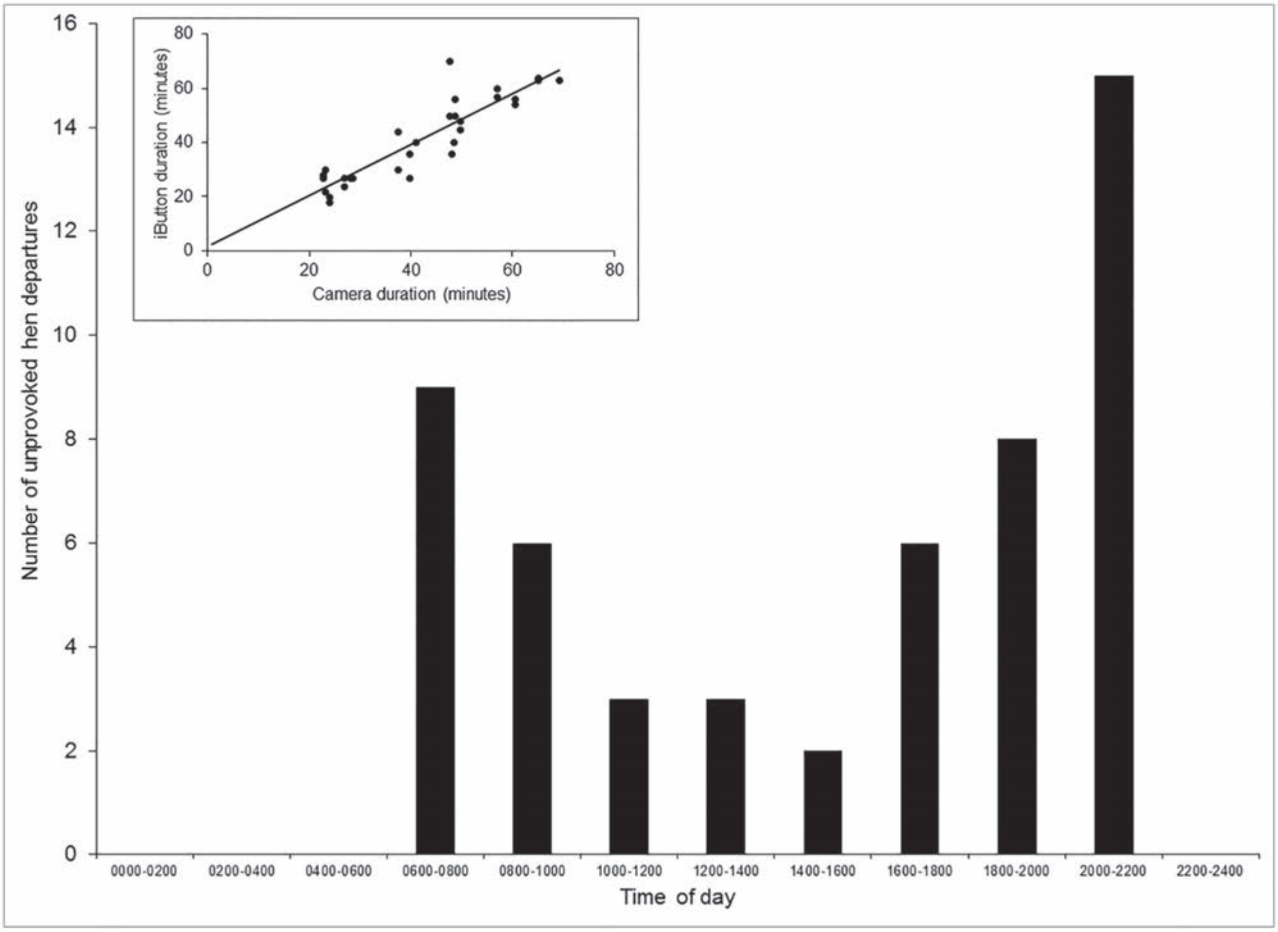

Figure 2. Frequency of unprovoked nest departures of greater prairie-chicken hens ($N = 52$) during 2-hour time periods, with inset comparing duration of greater prairie-chicken nest absences, as measured by iButtons and video cameras ($r^2 = 0.80$) at nests in Rock and Brown Counties, Nebraska, USA, between May and June 2011.

age: https://youtu.be/LP4NV6yivMQ). Video surveillance did not begin again until 1 June, when technicians reattached the power cable to the camera. On 3 June, a 40-min recording section of the continuous video was deleted accidently when the camera's secure-digital (SD) card was switched out. The average lag time of iButtons set at 4- and 9-min recording intervals was –1 min, 22 sec, and –4 min, 12 sec, respectively (Table 1), which suggests that the use of 4-min intervals resulted in less error in determining when the nest was incubated than the longer 9-min recording intervals. The iButton placed ~1 m outside the nest to measure ambient temperature appeared to have been pushed deeper in the soil during the hailstorm; however, prior to the hailstorm this "control" iButton's temperature graph revealed a daily sine curve of low temperatures at night and high temperatures during the day. On one occasion, the iButtons set to record at 4- and 9-minute intervals failed to display a drop in temperature during an absence. Video showed that the hen had left for 25 min on a warm afternoon and the nest temperature stayed relatively constant, thus indicating nest temperature did not change due to the high ambient temperature.

On 16 May 2011 we flushed the hen at nest #362, put in place the iButton and nest camera, and monitored the nest for 4 days (16 to 20 May). At 1327 on 20 May, a rodent was filmed at the nest; 2 hours later we found the nest absent of eggs. Average lag time was inestimable because only one error in absence was detected between iButton and camera during this nest's short lifespan.

Nest #542 was initiated on around 12 May and was monitored for 8 days (16 to 24 May 2011). The nest was lost to coyote (*Canis latrans*) depredation around 2300 on 21 May except for one egg. The egg was 9–12 days along in growth. The average lag time, departure lag time, and arrival lag time for the iButton set at 2-min

TABLE 1. Data from iButton analysis of greater prairie-chicken nests in Rock and Brown Counties, Nebraska, USA, between May and June 2011.

Nest number (iButton interval)	Mean nest temperature (°C)	Mean lag time	Mean hen-departure lag time	Mean hen-arrival lag time	Number (and percentage) of iButton-detected camera-documented absences
001 (4 min)	33.34	–0:01:22	0:00:23	–0:00:47	8/9 (89%)
001 (9 min)	33.17	–0:04:12	–0:02:11	–0:05:37	12/13 (92%)
362 (3 min)	22.36	—	—	—	2/2 (100%)
362 (15 min)	21.16	—	—	—	1/2 (50%)
542 (2 min)	26.66	0:01:54	0:02:50	0:04:44	9/10 (90%)
542 (10 min)	22.51	0:01:29	–0:04:51	–0:03:23	11/13 (85%)
Average	—	–0:01:05	–0:01:22	–0:02:10	42/49 (86%)

Note: Lag times indicate deviation of iButton detection before and after actual (camera-documented) times, denoted by negative and positive values, respectively.

recording intervals occurred after the actual time that the hen departed or returned to the nest, whereas the average arrival and departure times of the 10-min iButton occurred before the actual time and after the actual time for the average lag time, respectively (Table 1).

Conclusions

Overall, the overlap between video footage and iButton data was optimized when the iButton was set at a 10-min recording interval. An iButton set to 10 minutes will keep recording data without overwriting previously recorded data for approximately 14 days. Placing two iButtons in a nest and programming one to begin recording after 14 days would allow nest monitoring for an entire prairie-chicken nest incubation period (~25 days). If multiple human visits occur during their incubation period, a 4-min interval may provide the most temporally resolute information for prairie grouse nest monitoring. However, these recommendations are based on low replications of time intervals and a small sample size.

iButtons provided an effective way to monitor prairie-chicken nests by ascertaining daily nest status and timing of nest failure. Daily nest status was identifiable through iButton readings which were validated by scoring camera footage. The iButtons showed nest absences with 88% accuracy. The maintenance of a set nest temperature of ~33°C was revealed by iButtons whenever the hen started an incubation bout. A "V" shape in the graph was typically depicted when a hen left the nest. An extended leave showed a "V" in the graph that was very noticeable, while short-term absences were generally less evident. The lowest point (temperature) on the graph was almost always recorded immediately before the time a hen returned to tend the nest. Similar findings using iButton readings have been reported in other large ground-nesting birds (Hartman and Oring 2006; Wilson and Martin 2010). In contrast to our study, these studies did not confirm nest absences with video footage.

Our video camera analysis, which corroborated iButton-derived nest attendance, also recorded unique footage of nest predations by a bull snake (S1), coyote, and an unidentifiable small rodent. The control camera, however, did not attract any carnivorous predators into view of the camera. There are contrasting views of the effect that video camera presence at nesting sites has on the frequency of predator visitations (Richardson et al. 2009; Powell et al. 2012). For example, Powell et al. (2012) found higher predation rates in ground-nesting western meadowlark (*Sturnella neglecta*) nests when the nests were filmed to determine activity, whereas a meta-analysis by Richardson et al. (2009) suggested that on average, nest cameras may reduce the risk of nest predation of several bird species.

Understanding the efficacy of nest monitoring techniques for species of conservation concern such as the greater prairie-chicken, which exhibit uniparental care of offspring and rarely re-nest after brood loss in a single breeding season (McNew and White 2012), is paramount to their conservation because maximizing data quality at the lowest expense can improve management efforts of this vulnerable species. Although there have been many studies of nest attendance in birds, few can be practically applied to ground-nesting prairie grouse. Our study suggests that iButtons could be effectively used in future studies to monitor hen absences from prairie grouse nests. Here, iButtons were unobtrusive, inexpensive, and able to effectively measure nest attentiveness of greater prairie-chickens. The two other prairie grouse of the North American Great Plains, lesser prairie-chicken (*T. pallidicinctus*) and sharp-tailed grouse (*T. phasianellus*), construct nests in a similar fashion to our study species (Rodewald 2015). Thus, our findings likely extend to these species as well, although high ambient temperature may mask the detection of lesser prairie-chicken hens' nest departure in the southern Great Plains. Therefore, a thorough investigation of iButton efficacy for this species of conservation concern is warranted.

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