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A temperature-based monitoring of nest attendance patterns and disturbance effects during incubation by ground-nesting sandgrouse

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ABSTRACT

Sandgrouse are birds of arid environments adapted to cope with extreme temperature variations. We used temperature data-loggers to remotely study incubation rhythms by pin-tailed and black-bellied sandgrouse in Spain. In both species, mates switched incubation roles twice a day, between 08:00 and 10:00 and between 19:30 and 21:30, when the nest and ambient temperature were most similar. During mate switches, sandgrouse preferred to risk a cooling rather than a warming of eggs. In the pin-tailed sandgrouse, the timing of morning switches was consistent within-pairs, while the timing of evening switches was more related to sunset time. Absences lasted longer following a disturbance than during a mate switch. During disturbances, changes in nest temperatures depended on the changes in outside temperature, and negatively correlated with absence duration. Absences following a disturbance were shorter when the outside temperature was higher. Nesting success was low (19%), with no noticeable effect of data-loggers. Our study highlights some of the constraints that birds breeding in arid environments, such as sandgrouse, face during incubation. It also stresses out the importance of evaluating the consequences of disturbances during incubation, in particular nest visits. Temperature data-loggers can provide an easy and effective way of monitoring nests, without the need of repeated nest visits.

1. Introduction

Knowledge of nest attendance patterns and incubation rhythms are key to our understanding of bird adaptations to extreme environments (Grant, 1982), the demands and energetic costs imposed on incubating parents (Reid et al., 2002; Thomson et al., 1998) and parental investment strategies and life-history trade-offs (Conway and Martín, 2000; Wiebe, 2001). It is also relevant to conservation and can inform about the timing and causes of breeding failures, and the potential effects of disturbance by humans (Ibañez-Alamo et al., 2012; Lloyd et al., 2000; Schneider and McWillams, 2007).

A wide variety of nest monitoring methods have been used in avian field studies, depending on the characteristics of the target species and monitoring aims. Direct observations of nests are time-consuming and often not feasible or desirable, because the nest content sometimes cannot be observed from a distance, or because the presence of an observer may alter parental behaviour and be a source of disturbance and a cause of nest failure (Carey, 2011; Götmark, 1992; Ibanez-Alamo et al., 2012; Weidinger, 2006). When direct observations of nest activity are not feasible or desirable, researchers have used alternative means of monitoring nest activity, such as video camera recordings, electronic balances, light-sensitive and temperature data-loggers.

Temperature data-loggers have been successfully used to determine when a bird is on or off the nest (e.g. Arnold et al., 2006; Weathers and Sullivan, 1989; Weidinger, 2006) and may be particularly suited for studying incubation rhythms of birds in arid environments, where thermal conditions are critical. Technological advances have produced data-loggers that are smaller, more accurate and with greater battery and data storage capacities. During incubation, data-logger methods generate times series that can be used to determine the thermal conditions experienced by incubating birds, as well as the occurrence (timing, frequency) and duration of absences from the nest (hereafter off-bouts), by comparing the nest temperature with the outside temperature. Data-logger methods also allow studying the effects of disturbances, such as nest visits, as well as the breeding phenology and nest survival (Schneider and McWilllams, 2007; Weidinger, 2006).

In this study, we used for the first time temperature data-loggers to study the nest attendance patterns and the effects of

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nest visits during incubation by two birds typical of arid environments: the pin-tailed sandgrouse (*Pterocles alchata*, Linnaeus 1766) and the black-bellied sandgrouse (*Pterocles orientalis*, Linnaeus 1758) in Spain. Sandgrouse nest on the ground and have to cope with extreme temperature variations during incubation, which makes them of particular interest for studying incubation rhythms. Our specific aims were as follows: 1) to document the range of temperatures experienced by incubating birds and their clutch; 2) to determine the timing and duration of off-bouts; 3) to analyse within- and between-pair variation in the timing and duration of off-bouts (when mates normally switch incubation roles); 4) to relate the timings of mate switches to thermal conditions (differences between the nest and control temperatures); and 5) to evaluate the effects of nest visits and other disturbances (which may be by people other than researchers or predators) by determining how long a bird takes to resume incubation after a disturbance and the consequences of absences from the nest, in terms of exposure of the clutch to potentially harmful temperatures. We use the information to highlight the benefits and limitations of temperature data-loggers for monitoring nests during incubation, and to give recommendations for optimizing the breeding monitoring of sandgrouse and other birds living in similar arid environments.

2. Materials and methods

2.1. Study species

Sandgrouse (family *Pteroclidae*) are medium-sized ground-nesting steppe-birds that are particularly difficult to observe because of their cryptic and well camouflaged plumage, discrete behaviour and sensitivity to human disturbance (De Juana, 1997). Sandgrouse are well adapted to cope with deserts and arid environments (Hinsley, 1992; Johnsgard, 1991; Thomas, 1984; Thomas and Maclean, 1981). These adaptations include a dense plumage and thick feet to increase isolation from extreme thermal conditions, heat regulation based on high evaporation rates and peculiar behaviour such as regular visits to waterholes for drinking and water transportation to chicks (Hinsley, 1992; Johnsgard, 1991; Marder et al., 1986; Thomas, 1984; Thomas and Maclean, 1981; Thomas and Robin, 1977).

The pin-tailed and black-bellied sandgrouse are typical of dry steppes and extensive agricultural habitats (del Hoyo et al., 1997; Benítez-López et al., in press). Both species have a “Least Concern” (LC) conservation status in Europe (BirdLife International, 2004; De Juana, 1997) and a “Vulnerable” status in Spain, due to recent population declines (Suárez and Herranz, 2004a,b; Suárez et al., 2006).

While some aspects of their general ecology have been studied, such as their distribution and habitat preferences (Martín et al., 2010a,b; Seoane et al., 2010; Suárez et al., 1997), other aspects, and in particular their breeding biology, are still poorly known (De Borbón et al., 1999b; De Juana, 1997; Znari et al., 2006). Pin-tailed and black-bellied sandgrouse are socially monogamous, and both sexes share reproductive duties, mainly to distribute the high demands associated with breeding in arid environments (De Juana, 1997; Johnsgard, 1991). Mates take turns to incubate the clutch and switch incubation roles in the morning and in the evening (Johnsgard, 1991; Marchant, 1961). The female typically attend the nest during the day, and the male attend it from dusk until mid-morning; during mate switches, the bird leaving the nest typically first visits a drinking place, and then feeds and rests before resuming its incubation duty (De Borbón et al., 1999b; De Juana, 1997). Young leave the nest soon after hatching (De Juana, 1997).

Breeding takes place from late spring to late summer, depending on the latitude, with clutches being usually laid in May–August and in June–September by pin-tailed and black-bellied sandgrouse, respectively (De Borbón et al., 1999b; Znari et al., 2008). Nests typically consist of a 10–15 cm wide shallow depression on the ground in an area with no or low vegetation cover, unlined or with a few pieces of dried grass (Fig. 1).

2.2. Study areas and field procedures

Fieldwork was conducted in May–August 2011 in Spain, in two study areas located in Campo de Calatrava, Castilla-La-Mancha, Ciudad Real province (Special Protection Area – SPA-157; 38° 54′N, 3° 55′W) and in the Bardenas Reales Biosphere Reserve and Natural Park, Navarra province (42° 08′N, 1° 26′W). These areas were characterized by agro-steppes (Ciudad Real), and by natural steppes and/or ploughed fields or barren areas with low vegetation cover (Bardenas Reales).

Sandgrouse nests were located by means of conventional radio-tracking of birds previously caught and fitted with radio-transmitters (see Benítez-López et al., 2011; Martín et al., 2010a,b for details on the capture method and tags), or by systematic search and field observations of unmarked individuals. When breeding was suspected (i.e. when a bird was repeatedly located within the same area, and was observed without its partner indicating that its mate may have started incubation), we searched for the nest. To do so, we walked towards its putative location. When an observer approaches a nest, incubating sandgrouse typically walk away and take off from a short distance. We land marked the last location where the bird was seen and carefully searched around it to locate the nest. Each nest position was recorded using a GPS (Garmin eTrex) to the nearest 3–4 m in order to facilitate relocation.

2.3. Temperature recordings

We used DS1923 Hygrochron Temperature/Humidity Logger i-Buttons with a 8 kb data-log memory (Maxim/Dallas Semiconductor Corp; Fig. 1) for temperature recordings. These data-loggers record temperature ranging between −20 °C and +85 °C, with an accuracy ±0.5 °C in the range −10 °C to +65 °C.

For each study nest, we set-up two temperature data-loggers: one was placed inside the nest, underneath the nest lining material and the eggs, and covered by a thin layer of soil so that it could not be seen by the birds (hereafter nest data-logger), and the other one was placed at c.1 m away from the nest, also covered by a thin layer of soil (hereafter control data-logger). The location of the control data-logger was chosen to have similar vegetation, shading conditions and substrate as its corresponding nest data-logger. Data-loggers were programmed to record temperature every 5 min during a maximum period of 28 days (the data storage capacity of the i-Buttons). This programming ensured covering the whole incubation period, known to last 20–22 and 26 days in pin-tailed and black-bellied sandgrouse, respectively (De Borbón et al., 1999b; del Hoyo et al., 1997).

Nest monitoring included nest visits (during which we flushed the incubating bird to check the nest content) and triangulations (to check for the presence a radio-tagged bird at the nest from a distance of 50–100 m, without flushing the incubating bird; Table 1). Nests were visited in the morning between 06.40 and 11.00 or in the afternoon between 18.30 and 21.00, with one exception in mid-day (12.25). The repeated absence of a tagged bird from a nest during its normal period of nest attendance would indicate that the eggs had either hatched (chicks leave the nest with their parents after hatching) or that the nest had failed and the parents deserted it. For each nest visit and triangulation, we recorded the day and time of the visit, the presence of an incubating bird, as well as the nest content (for nest visits only). At the end of