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Short communication

Diurnal variation in nest material use by the Kentish Plover *Charadrius alexandrinus*

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Most birds use nest materials around their eggs (Collias & Collias 1984, Hansell 2000). In ground-nesting birds such as waders nest materials appear to have two major functions. First, nest materials reduce the temperature fluctuations of eggs by insulating them from the ambient environment. This promotes embryonic development by providing a stable thermal environment (Møller 1991, Reid *et al.* 2002). Good insulation may also reduce the energetic costs of incubation for parent birds (Williams 1996). Secondly, nest materials may provide camouflage and thus conceal the eggs from visually searching egg predators (Solís & Lope 1995).

However, using nest materials may carry costs; for instance the parents have to spend time and energy to collect them (Moreno *et al.* 1994), and extreme amounts of nest material may isolate the eggs from the brood patch of parents (Deeming 2002). At high ambient temperatures nest materials may increase the temperature of the eggs and thus endanger the embryos (Webb 1987, S. Lengyel & T. Székely unpubl. data).

The amount of nest material is expected to change with the costs and benefits of nest materials in relation to the ambient environment. For instance, Barn Swallows *Hirundo rustica* reduce the amount of nest lining during their nestling period (Møller 1987), and one explanation proposed for this behaviour was that the risk of hyperthermia increases over the nestling period. In addition, some waders cover their eggs with nest material when they leave their nest (Howell 1986) or when predators approach the nest (Maclean 1974). Taken together, these observations suggest that parents monitor the amount of nest material, and regulate it if necessary. This hypothesis, however, has rarely been tested.

Here we report that Kentish Plovers *Charadrius alexandrinus* adjust the amount of nest material during the day. This adjustment is expected because Kentish Plovers nest in open habitats where the eggs are largely exposed to the ambient temperature and predators, and both of these factors change over the day. The Kentish Plover is a small, ground-nesting wader that scrapes its nest into open ground, and lines the nest with grass, pebbles and mollusc shells (Szentirmai & Székely 2002). The modal clutch size is three eggs and both parents participate in incubation (Kosztolányi & Székely 2002).

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METHODS

We investigated the Kentish Plovers at Lake Tuzla in southern Turkey (36°42′N, 35°03′E) between 29 May and 19 June 2000. We measured the exposure of eggs, i.e. the height of each egg (to the closest millimetre) that was above the level of nest material, and the volume of nest material (by placing it in a graduated cylinder), in 20 nests three times during a 24-h period. Each nest was visited in the morning (06:00–08:00 h, local time, GMT + 3 h), in the afternoon (14:00–16:00 h) and at night (22:00–24:00 h). The timing of the first visit was randomized. The detailed methods of nest measurements are described by Szentirmai and Székely (2002). Ambient temperature was recorded by an automatic data logger (Tinytag, Gemini Data Loggers Ltd) every 5 min at 10 cm above ground level in a location central to the study area. The temperature range recorded was 14.1–40.4 °C. Spur-winged Plovers *Hoplopterus spinosus* and Montagu's Harriers *Circus pygargus* prey on nests during the daytime, whereas Hedgehogs *Erinaceus concolor*, Jackals *Canis aureus* and straying dogs *Canis familiaris* prey on nests at night.

Data were analysed by repeated-measures general linear models (GLMs, one model each for nest material volume and exposure) that included daytime as factor and ambient temperature as covariate. We used SPSS 9.0, and provide the mean ± se and two-tailed probabilities.

RESULTS

Both the volume of nest material and the exposure of eggs changed significantly over the day (Fig. 1, repeated-measures GLMs, volume: $F_{2,37} = 13.060$, $P < 0.001$; exposure: $F_{2,37} = 25.166$, $P < 0.001$). Volume increased from midnight through morning to afternoon, whereas exposure decreased from midnight through morning to afternoon (Figs 1 & 2). All changes were significant using orthogonal contrasts between morning and afternoon (volume: $F_{1,19} = 21.345$, $P < 0.001$; exposure: $F_{1,19} = 8.043$, $P = 0.011$), between afternoon and night (volume: $F_{1,19} = 62.277$, $P < 0.001$; exposure: $F_{1,19} = 56.316$, $P < 0.001$), and between night and morning (volume: $F_{1,19} = 4.490$, $P = 0.048$; exposure: $F_{1,19} = 22.734$, $P < 0.001$).

Ambient temperatures differed between morning (20.3 °C ± 0.5 se), afternoon (32.3 °C ± 0.4 se) and night (25.5 °C ± 0.5 se), suggesting that the diurnal changes in

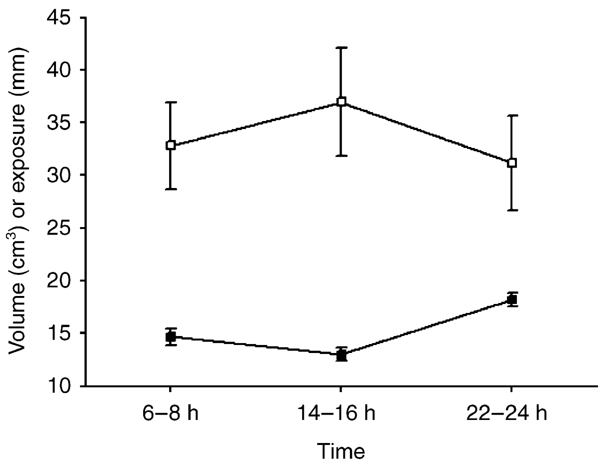

Figure 1. Diurnal variation in volume of nest materials (□) and exposure of eggs (■) in 20 Kentish Plover nests (mean ± se).

the amount of nest material (and exposure) might be explained by changes in ambient temperature. However, this explanation is unlikely because the ambient temperature was not significant in the GLM of nest material volume ($F_{1,37} = 1.513$, $P = 0.226$) and egg exposure ($F_{1,37} = 0.326$, $P = 0.572$). Taken together, diurnal variation in both nest material volume and exposure of eggs remains significant when ambient temperature is statistically controlled for.

DISCUSSION

Kentish Plovers actively regulate the amount of their nest material: they cover the eggs with nest material during the day, and uncover them at night. Regulation is achieved by adding and removing material from the nest, and by manipulating the amount of nest material above and beneath the eggs (I. Szentirmai pers. obs., Szentirmai & Székely 2002). These results are among the first to demonstrate that ground-nesting birds regulate the eggs' environment on such a short time-scale. Our results are consistent with the observation of Orr (1999) at a single nest of Kentish Plover, as well as with the results of our experimental study in which we showed that parents restored the original amount of nest material in about a day (Szentirmai & Székely 2002).

One explanation for this behaviour might be that parents adjust the amount of nest material in relation to ambient temperature. However, this explanation is unlikely in isolation. It is more plausible that the amount of nest material is related to the risk of nest predation, or that both predation risk and environmental insulation affect the amount of nest material. In line with the first argument, the amount of nest material was greater in the morning and afternoon, when visually searching predators are active on our study site, than it was at night (I. Szentirmai & T. Székely pers. obs.). In line with the second argument, there is more need for insulation in the daytime when parents often leave their nests, than at night when they incubate almost continuously (Kosztolányi & Székely 2002). Camouflage of eggs would be important, because approximately 49% of Kentish Plover nests are predated (I. Szentirmai & T. Székely unpubl. data).

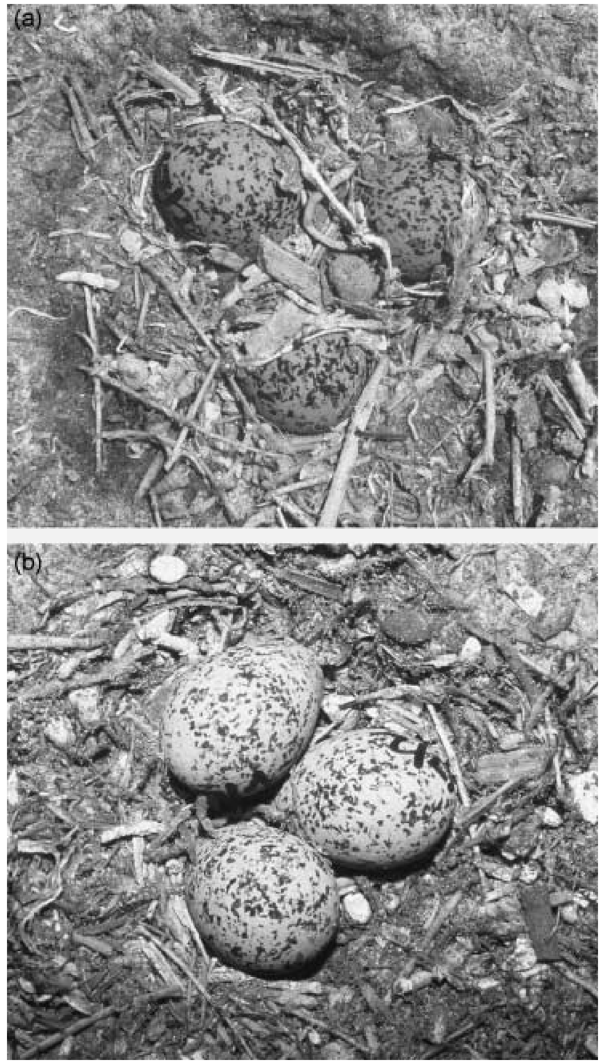

Figure 2. The same Kentish Plover nest at 11:30 h (a), and at 22:10 h (b) on 18 June 2000. Note that the eggs are buried in the daytime and uncovered at night.

An alternative explanation for the observed diurnal pattern may be that parents adjust the amount of nest material in relation to the strength of solar irradiation. In accord with this, large amounts of nest material may shade the eggs during the day when the parent leaves the nest for short periods, so preventing the eggs from overheating (Webb 1987).

However, if covering by nest material protects the eggs from both predators and irradiation, why do not parents maintain the high level of cover throughout the whole day? One explanation may be that large amounts of nest material might hinder heat transmission between the eggs and the parent's brood patch, and thus decrease the efficiency of incubation (Deeming 2002). This explanation is consistent with the observation that Kentish Plovers incubate nearly continuously at night, whereas they frequently leave their nest during the day (Kosztolányi & Székely 2002). Further studies, especially experiments, are needed to determine the relevant ecological and physiological factors affecting the parents' behaviour and the optimal amount of nest material in ground-nesting waders.

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