Temperature inside nest boxes of little penguins

Yan Ropert-Coudert, Belinda Cannell, and Akiko Kato

Abstract In order to assess the potential impact that artificial nest boxes may have on the occupation rate or physical condition of adults and chicks of little penguins (*Eudyptula minor*), we recorded temperature continuously for 37 days simultaneously inside 7 nest boxes and in surrounding bush. Temperature inside the boxes was always higher than that in the bush, the difference being greatest around noon. Solar radiation caused temperature inside the boxes to increase. Temperature differences between box interiors and exteriors were smaller on windy and dry days. To prevent hyperthermic conditions, we suggest improvements in the ventilation of nest boxes.

Key words breeding, chick, *Eudyptula minor*, hyperthermia, little penguin, nest boxes, temperature, Western Australia

Seabirds using a marine environment in which heat losses by conduction are substantial present a series of adaptations to hypothermia (see Calder and King 1974). The greatest adaptations are found in those species foraging in extremely cold polar waters (e.g., Alcidae spp. in the Northern Hemisphere and Spheniscidae spp. in the Southern Hemisphere). However, penguins also breed on land over a vast range of latitudes from the Antarctic continent to the Galapagos Islands. For those penguin species breeding in temperate ecosystems, such as the little penguin (*Eudyptula minor*) that breeds around southern Australia, Tasmania, and in New Zealand (Marchant and Higgins 1990), hyperthermic conditions sometimes may occur.

To shelter from the diurnal high temperatures, little penguins generally nest under local bush species or inside natural or artificial burrows (Marchant and Higgins 1990). On Penguin Island, Western Australia, which harbors the largest colony of little penguins in this state, the sand is too soft for burrows. Penguins here nest in caves of limestone, rock crevices, under bushes growing mainly <1 m above the ground (Dunlop et al. 1988, see Klomp et al. 1991) and in nest boxes placed in various localities on the island (Klomp et al.1991). These nest boxes serve a double purpose: they provide shelter for birds against predation or harsh weather conditions, and they facilitate scientific observations (see Wilson 1986, Priddel and Carlile 1995). Although little penguins are well accustomed to using nest boxes for their breeding cycle (Meathrel and Klomp 1990), their use of artificial nests for breeding remains low.

In austral spring 2002, temperature data were monitored continuously for 37 days in nest boxes, the surrounding bush, and in the air. We describe the range of temperatures that can be experienced by little penguins in artificial nest boxes so as to further improve box design and hence the breeding condition of little penguins and other seabirds.

Methods

We recorded temperature data from 24 August 2002 (0000 hours) to 1 October 2002 (2300 hours) within a colony of approximately 1,000–1,200 little penguins nesting on the central part of Penguin Island (32°17′S, 115°41′E), Rockingham, Western Australia (Figure 1). We recorded temperature inside and outside 7 nest boxes, which were placed

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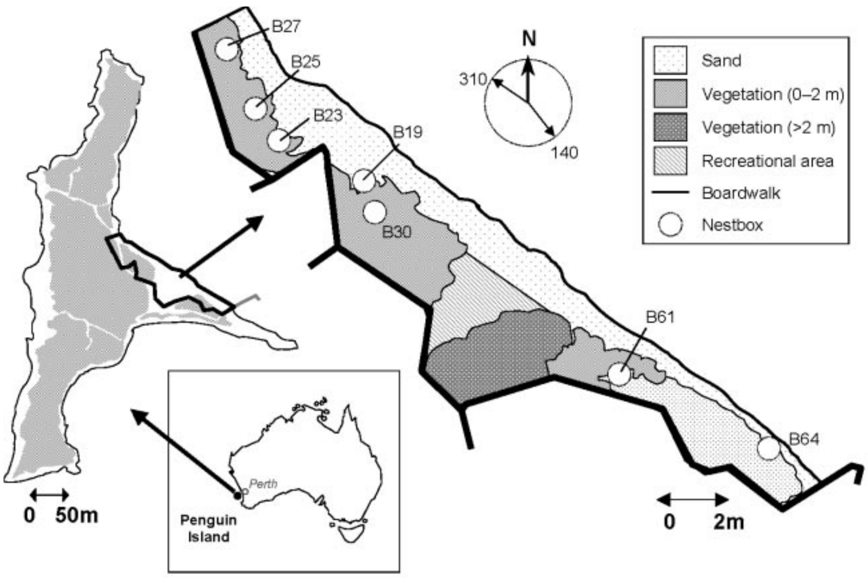

Figure 1. Penguin Island is located on the western coast of Australia, 600 m from Rockingham, Perth. Nest boxes equipped with temperature data-loggers were placed on a transect that runs along the eastern coast of the island. Vegetation surrounding the boxes was mainly <2 m in height.

along a transect orientated W–NW running approximately along the seacoast. The island was open to tourists between about 1000–1600 hours from May–September, but people had no direct access to the nest boxes. The rectangular plywood boxes, 0.9 × 0.4 × 0.4 m, had a removable roof and were surrounded by bushes of sea spinach (*Tetragonia decumbens*) and true spinifex (*Spinifex longifolius*). We determined an index of solar exposure using the percentage of the surface of the box (roof and 4 sides) that was in the sun at noon on the day of logger deployment.

We used 12-bit-resolution, 16-megabyte-memory, 2-channel UME-TT loggers (Little Leonardo, Tokyo, Japan) to record temperature every minute. Each of these silver, titanium-housed, cylindrical loggers (102 × 20 mm, 14 g in the air, absolute accuracy for temperature 0.1°C) had 2 thermosensors located at the end of 27.5-cm cables that emerged from the end of the logger body. We attached all loggers using marine Tesa tape (Beiersdorf AG, GmbH, Hamburg, Germany) inside nest boxes, against a wall. We attached inside sensors close to the ground and attached outside sensors on a branch inside the surrounding bush as deep as the cable length permitted (approx. 5–10 cm inside the bush). In addition to the data recorded by the loggers, we obtained meteorological data (including average temperature, wind speed and direction, and humidity), collected every 3 hours at the meteorological station of Garden Island (32°23′S, 115°68′ E), from the regional office of Perth, Commonwealth Bureau of Meteorology, Australia. Sunset and sunrise occurred at approximately 1800 and 0600 hours local time, between 24 August and 1 October 2002 (Bureau des Ephémérides, Paris, http://www.bdl.fr/).

Temperature difference (T_d) was defined as:

$$T_d = T_i - T_o,$$

where T_i and T_o stand for the temperature values recorded inside and outside of the nest-boxes, respectively. A positive T_d represents a temperature inside the box higher than that outside. We first averaged temperatures recorded by loggers on an hourly basis, then averaged on a daily basis. To compare effects of humidity on the temperature variations, we selected the 2 days with the highest and lowest average percentage of humidity (9 and 29 September, respectively) using the meteorological data collected at Garden Island. Similarly, we determined the day with the strongest and weakest wind speeds (14 and 20 September, respectively) using average wind-speed values calculated on days for which >70% of the daily wind data recorded were oriented between 140°SE – 310°NW (i.e., wind orientation that was most likely to have an effect on the environment where boxes were, cf. Figure 1). We checked occupation of boxes by breeding little penguins (i.e., presence of 1 or 2 adults with eggs or chicks) on the first day of logger placement. On the first day, 3 boxes were occupied: B30 had 1 adult and 1 egg, and both B27 and B19 had 1 adult and 2 eggs. We found adult pairs without eggs in boxes 64 and 23 on the first day of logger placement, but they were not seen again in the box in the 2 subsequent days.

We treated comparisons between the temperature inside and outside the boxes using a paired Student's *t*-test, following the procedures recommended by Sokal and Rohlf (1969). The statistical threshold was 5%. Values are presented as average and standard deviation (±SD)

Results

Overall, T_i (16.48 ± 4.63°C) was significantly greater (t-test, t_{6551} = 53.29, P < 0.0001, Figure 2*a*) than T_o (15.45±3.87°C), except between 0600 and 0900 hours for 2 boxes (B23, B61) for which the temperature difference (T_d) became slightly negative (ranging from –0.14 to –0.63°C). The maximum T_d (6.17°C) was recorded at 1300 hours in box 64, while the average maximum T_d over all boxes was 2.73 ± 1.65°C (n = 6). Overall, daily T_d (1.64±1.96°C) was significantly greater (t-test, t_{3002} = 27.51, P < 0.0001) than T_d recorded during night times (0.51 ± 0.83°C). Both daily (19.48 ± 4.82°C) and night T_i (13.95±2.42°C) statistically differed (t-test for daily differences: t_{3002} = 45.84, P < 0.0001; and night differences: t_{3548} = 36.9, P < 0.0001) from daily (17.84 ± 3.88°C) and night T_o (13.43 ± 2.46°C). The highest T_i recorded during the study period was 43.81°C (recorded in box 64 for which 96% of the surface was exposed at noon). Based on the percentage of the box exposed in the sun, daily T_i appeared to be related to intensity of the solar exposure received at the surface of the box (Figure 2*b*). Trends were less clear during nighttime, although T_i appeared slightly greater in the case of well-covered boxes. Finally, T_d during humid (1.78 ± 1.20°C) and calm (1.50 ± 1.05°C) days was greater (t_{23} = 4.19, P = 0.0004 for humidity; t_{23} = 7.08, P < 0.0001 for wind speed) than T_d during dry (0.92 ± 1.27°C) and windy (0.51 ± 0.50°C) days (Figure 3). However, both T_i and T_o were greater throughout the day during dry and calm days than during humid and windy days.

Discussion

Results obtained in this study stress the importance of recording temperature data locally as well

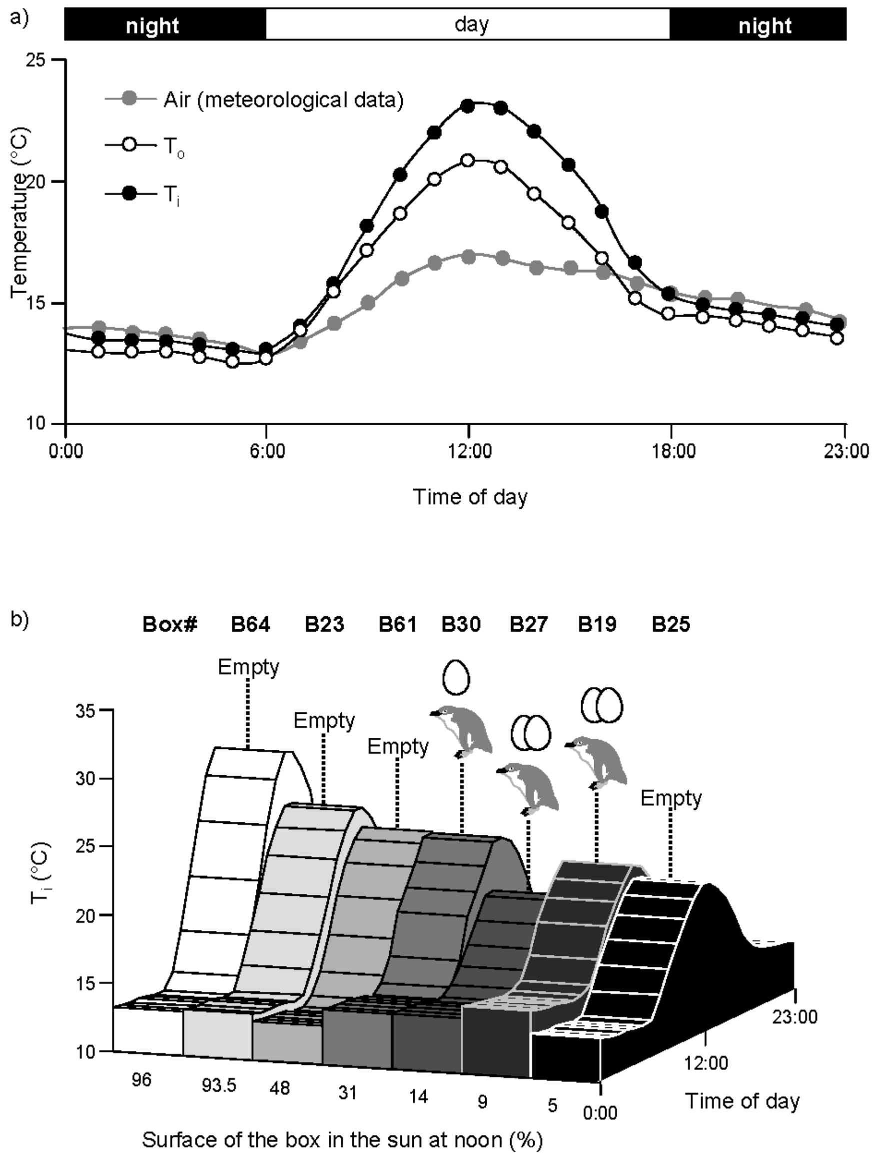

Figure 2. *a*) Hourly temperatures averaged over the study period as recorded by data-loggers placed inside (T_i) and outside (T_o) nest boxes of little penguins and by a meteorological station located on neighboring Garden Island, Western Australia, 2002. *b*) Hourly temperatures recorded inside nest boxes averaged over the study period and presented separately for each nest box according to the box's degrees of solar exposure (see text for calculation of the index of solar exposure). Information about the occupation of nest boxes by breeding little penguins is given above the temperature graphs.

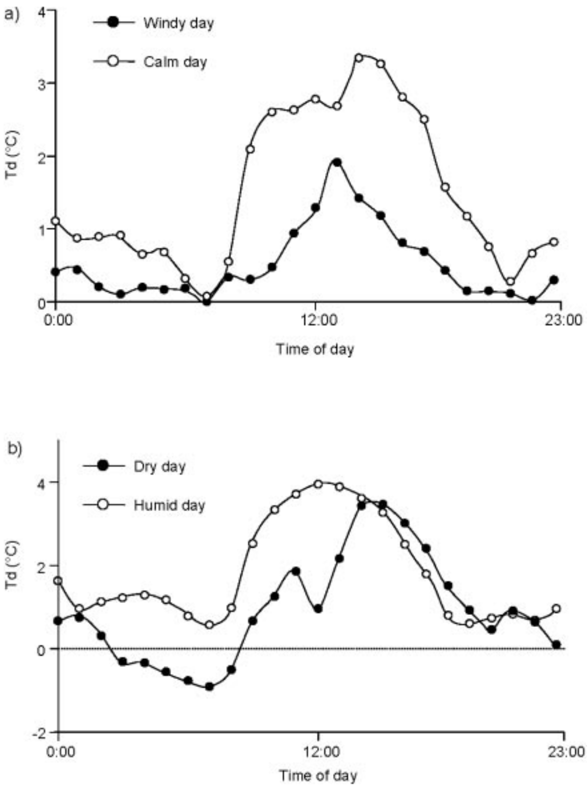

Figure 3. Hourly temperature differences between inside and outside (T_d) little penguin nest boxes, 2002, presented for *a*) the windiest day (closed circles) and the calmest day (open circles); and *b*) the driest day (closed circles) and the most moist day (open circles).

as simultaneously in different nesting sites of burrowing seabirds (i.e., in the burrows, the air, the bush, and the nest boxes). To our knowledge, the temperature inside nest boxes of little penguins has been reported only once. Klomp et al. (1991) measured the temperature once a day at 1400 hours local time on 6 dates from 2 November 1986 to 5 January 1987. These authors also measured temperatures in caves, under bushes, and in 2 categories of nest boxes defined as lightly and heavily shaded. They found no significant variation of temperature between the air and the different nesting sites used by little penguins, each providing little protection against insulation and wind (Klomp et al. 1991). Results from our study demonstrate that a single measurement does not reflect the actual range of temperature experienced by nesting little penguins on a 24-hour basis. Klomp et al. (1991) found only little differences between air and nest temperature, while our data showed significant differences. It should be noted that the temperature recorded by the sensor placed outside the boxes may have been occasionally directly under the sun. Thus, T_o may have been overestimated due to the effect of solar radiation.

However, temperature recorded inside the nest box was mostly greater than that recorded outside, especially for boxes with little shade cover. Indeed, solar radiation appeared to be the main factor responsible for the high temperatures recorded in the box. Wind and humidity, on the other hand, tended to attenuate the effects of solar radiation, cooling the air in and outside the box. These results indicate that the maximum temperatures experienced by little penguins in the nest box may likely reflect the most unfavorable conditions for the birds. Given that the temperature recorded in the bush during the day was always significantly lower than that in the box, bushes of *Tetragonia decumbens* and *Spinifex longifolius* seem to provide an efficient thermal refuge for birds. This was similar to the findings by Frost et al. (1976) for burrows of African penguins (*Spheniscus demersus*).

In 2000 and 2001, the percentages of nest boxes occupied by adult pairs of little penguins on Penguin Island were 65 and 71%, respectively. However, only 42 and 43% of these boxes had eggs laid in them in 2000 and 2001, respectively (B. Cannell, Murdoch University, unpublished data). Various methods (e.g., degree of camouflage, proximity to human activities, accessibility) have been proposed to discourage penguins from occupying nest boxes (see Klomp et al. 1991). The results obtained in our study indicate that temperature should also and equally be considered as potentially detrimental for occupation of a nest box, although it obviously cannot be considered a determinant factor in itself. In our study, well-shadowed boxes (except B25) were occupied by breeders (at least at the beginning of the study period). Although we could not check on the presence of little penguins throughout the study period, temperature's contribution to the non-occupation of nest boxes appears especially plausible in the case of birds breeding on Penguin Island, one of the northernmost colonies in Australia (Marchant and Higgins 1990). Here, summer air temperature can rise to 40°C toward the end of the breeding season (Klomp et al. 1991), a heat level that has been described as uncomfortable for little penguins (Stahel and Nicol 1982). Beyond discomfort, hyperthermia can be lethal for seabirds, especially those likely to be handled by humans, for stress has been shown to increase seabirds' body temperature

(Boyd and Sladen 1971). In addition, birds enduring hyperthermic conditions will tend to increase their body temperature by 2–4°C (Calder and King 1974).

In the case of little penguins, a series of parameters tends to render the situation even more critical. During the day, nest boxes are occupied by 1 or 2 chicks and perhaps 1 guarding parent (depending on the chicks' development stage), and each individual's body temperature contributes to increasing the temperature inside the box. Chicks are known to show a higher metabolic rate than adults, as demonstrated in Pygoscelids (Culik et al. 1990). In addition, chick down is a good insulator (Taylor 1985, Chappell et al. 1989). The most efficient way for a chick to avoid overheating, therefore, would be to increase the body surface available for convection (Despin et al. 1978, Chappell and Souza 1988). Hence, when chicks are inside a nest box with little or no ventilation, overheating may become problematic. Breeding success may consequently be affected.

In light of these results, we propose the following improvements for nest boxes in use on Penguin Island (Klomp et al. 1991) (Figure 4): 1) increase ventilation by attaching beads on top of 2 walls to raise the removable lid and allow air to flow; 2) improve both camouflage and heat absorption of the nest box by attaching branches of bushes to the removable lid and the box walls. This latter idea may increase the camouflage of the box without preventing a researcher from performing quick checks on the status of the penguins. In this regard, the presence of a floor in nest boxes has proven useful in the case of another burrowing species, the rhinoceros auklet (*Cerorhinca monocerata*) in Teuri Island, Japan (Kuroki et al. 1998) since auklets, as did little penguins in our site, tended to dig the ground under the boxes.

Management implications

In conserving and managing sensitive populations of surface-nesting and burrowing seabirds, it appears crucial to accurately assess the effect the artificial nests and scientific procedures may have on these species (Wilson 1986). Our study iterates the importance of obtaining temperature data from nest boxes placed in different habitats and insulation conditions. Future recordings of the temperature inside boxes placed in different habitats or insulation conditions should be accompanied by recordings of the body temperature of birds, especially chicks. Finally, our results apply to surface-nesting little penguins potentially facing hyperthermic conditions. *Eudyptula minor* breeding in colder habitats may sometimes be confronted with hypothermic stress, and the impact of nest-box conditions on these birds may be entirely different.

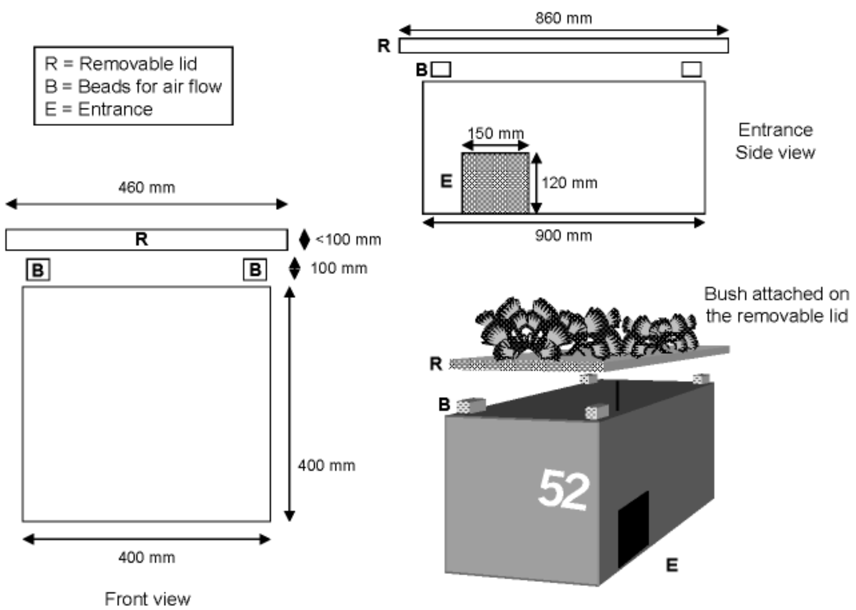

Figure 4. Frontal, lateral, and 3-D views of the nest boxes used on Penguin Island, with modifications suggested to improve the ventilation inside.

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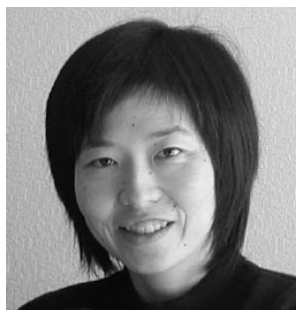

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